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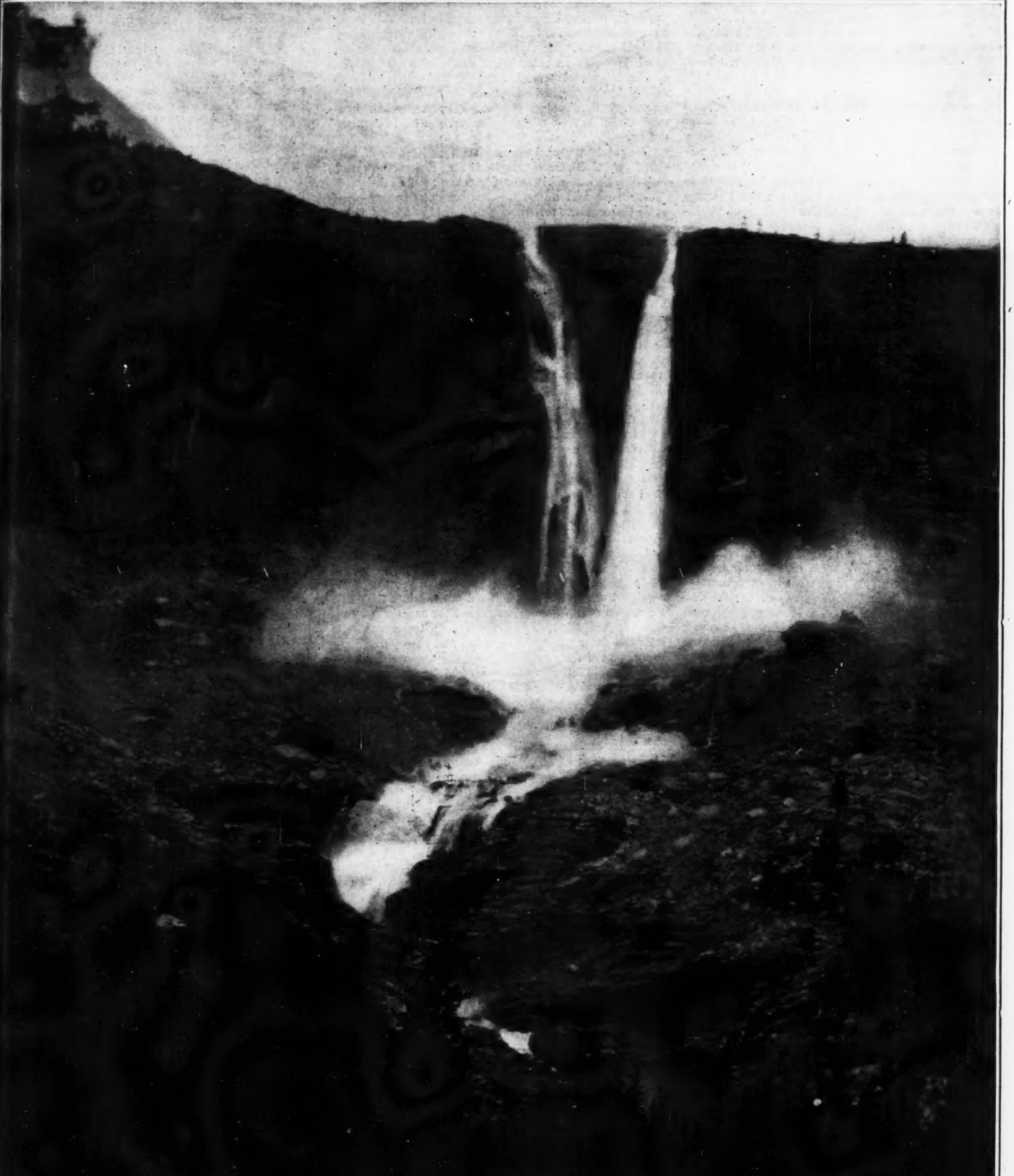


TWIN FALLS IN YOHO VALLEY, CANADIAN ROCKIES.—[See page 360.]

The Relation of Phrenology to the Study of Character*

Self-Deceptive and Shallow Psychological Notions

The last stage in the antecedents of the study of character represented a new rôle, or, it may be, an old one in a new and distinctive costume. In its practical effect and later career it resembles the system of Lavater, and invited yet greater popular abuse. Its founder was Dr. Franz Joseph Gall (1757–1828); and it achieved popularity under the name of *Phrenology*. While Lavater stood beyond the pale of the scientific activity of his day, Gall was an influential part of it. Gall's scientific service must be acknowledged even if he be held responsible for the extravagances of phrenology. The system was extended and popularized by Dr. Johann Caspar Spurzheim (1776–1832), Gall's associate, and his successor as leader of the movement.

There are two distinct aspects to the work of Gall and Spurzheim; and it is not easy to understand or to set forth just how the connection stood in the minds of these contributors to the anatomy and physiology of the nervous system, and advocates of the locations of elaborate mental faculties by means of cranial prominences. The two orders of contributions are difficult to reconcile either in spirit or in method. The motive of "character-reading" was operative, though restricted by scientific considerations. It was forcibly made the consummation of a system quite irrelevant to the purpose. In the end, the practical temper prevailed; and phrenology allied with physiognomy, palmistry or other character-reading pretenses, degenerated to the woeful state of a *declassé* pseudo-science. Its nearness to the illuminating truth served but to intensify the obscurity of its shadows. The contrast in the two spheres of the career of Gall and Spurzheim serves to explain why, as they traveled about Europe, they were by some called "a pair of vainglorious mountebanks," and by others placed with Newton and Galileo as illustrious contributors to science. Yet the fact that phrenology called larger attention to the study of character than had any other movement gives it an important place in a retrospective view.

The impressionistic origin of his phrenological interests is thus recounted by Gall. When at school, he was struck by the fact that his schoolmates had facilities independent of instruction; that one was musical, another artistically endowed, and that this innate ability rather than application was most decisive in determining progress. He seems to have been annoyed at being surpassed by schoolmates who had a capacity for memorizing; and in an inauspicious moment he observed that these schoolmates all had prominent eyes. At the university he directed his attention to students with prominent eyes, and persuaded himself that in every case such men had exceptionally good verbal memories; and thus was the fatal correlation made. Not unlike Lavater, he trusted to his "physiognomical sense" to recognize the prominences which were to find a local habitation and a name upon the phrenological chart. At church he observed the most devout of the attendants, detected what portions of the skull were well-developed in them, and discovered the organs of *veneration*. He compared the heads of murderers and found an organ of *murder*, and similarly studied the heads of thieves and located the organ of *theft*. He had organs for the pre-eminent quality of each of the five senses; an organ of *tune* for the musical, and one of number for the *mathematical*. He thus accumulated a group of some twenty-four organs (which Spurzheim enlarged to thirty-five or more), and in this contribution disclosed with strange unconcern at once his self-deception and the shallowness of his psychological notions.

The common assumptions of physiognomy and phrenology (as we readily detect, though not thus obvious to the minds of their defenders), are these: (1) that there are distinct mental traits, qualities or capacities, which ordinary human intercourse and observation reveal; (2) that these are caused by (or correlated with) prominent developments of the parts of the brain; (3) the critical assumption (presumably least explicit of all), that we may accept as established the relation whereby the one, the bodily feature, becomes the index of the other, the mental trait. The assumed principle of relation was plainly empirical, had no warrant in principle. The clue in all such systems was merely a sign or trademark displayed, in Lavater's theological view, by a beneficent Providence to indicate the virtues and vices of men. For phrenology the alleged principle was wholly different. It grew out of the subdivision of the functions of the brain. The evidence, it must be admitted, was sought by approved scientific methods. But the stupendous assumption was made that the presumption in favor of the *existence* of such specialized brain-areas included a *knowledge* of their *terms*, and that their nature was indicated by the specific differences in the observed traits of men; further, that such mental traits, giving rise to or conditioned by marked local development of brain-areas, could be detected in the corresponding prominences of the skull. So supremely unwarranted was the cumulative series of assumptions that the scientific knowledge and procedure associated with its alleged establishment failed to confer upon phrenology any more respectable status or accredited position than were accorded to the far more extravagant assumptions of physiognomy. Clearly, if the assumptions of phrenology held—itself an extravagant supposition—the study of character and temperament would be completely shaped by its conclusions. Since they are neither pertinent nor illuminating, physiological and psychological studies still have a message for the student of human nature.

The chief warrant for a further consideration of the position of Gall and Spurzheim is that their views came into direct contact with the advance in the knowledge of the nervous system, which—as will duly appear—became the requisite for true psychological progress. The central question at issue was whether the brain functioned as a whole, or whether distinct functions could be assigned to its several parts. The former position was defended by Flourens (1794–1867), who maintained that the removal of a part of the brain of a pigeon weakened the general intelligence, but that the intact portion still exercised the complete range of brain-functions, though with diminished efficiency. Gall's position required a detailed and specialized division of function. He drew attention to the fact that the mutilated pigeon, while retaining physical sight and hearing, became mentally blind to the meaning of what it was clearly able to see, and mentally deaf to the meaning of sounds; he drew attention to the important evidence supplied by the association of mental symptoms with injury or disease of different portions of the brain, and noted that these were very different according to the region affected. His contentions proved to be correct in fact, in interpretation, and in method. In this controversy Gall argued physiologically, not phrenologically. In another controversy the reverse was the case. Flourens restricted his conclusions of the unity of function to the cerebrum, and confirmed the experiments on pigeons which showed that the cerebellum regulated locomotion. Gall had made the cerebellum the organ of amativeness; if it regulated the love-affairs, it could not regulate the gait. He replied first physiologically, that the experiment was defective, and the motor impairment due to concomitant injury of other parts of the brain; and then phrenologically, that if the cerebellum were the organ of locomotion, it would follow that persons with large cerebellums should be acrobats, and asked whether women (who in Gall's view possessed a small cerebellum), "walked and danced with less regularity, less art, less grace than men." Controversies of this kind were futile in view of the wholly irreconcilable positions of the advocates. In the end, the phrenological position became an obsession.

At another point phrenology came in contact with the advances leading to modern psychology; this is in its alliance with the study of hypnotism in the career of James Braid (1795–1860). The remarkable insight of this investigator enabled him to recognize under disadvantageous conditions the true nature of this mental state as a partial disqualification of the nervous system; but it did not prevent his temporary subjection to the phrenological fallacy. He refuted the position that the hypnotic state was a histrionic deception; he demonstrated its reality, but unwittingly brought it within range of suggestion or self-deception. Later he realized the error of his earlier work; but his association with phrenology injured his reputation, and delayed the recognition of his pioneer work in a difficult field. The following suggests the course of the experiments:

> I placed a cork endwise over the organ of veneration and bound it in this position by a bandage under the chin. The patient thus hypnotized at once assumed the attitude of adoration, arose from his seat and knelt down as if engaged in prayer. On moving the cork forward, active benevolence was manifested, and on its being pushed back veneration again manifested itself.

This observation seems the very parody of science. It illustrates that prepossession, even in men of shrewd observation and ability, is disastrous to logical integrity; and further that not until the true nature of nervous functioning was established as a fundamental directive position in all psychological considerations, were false leads of this kind entirely discredited.

In view of the fact that the vogue of phrenology in the middle of the nineteenth century represents the largest collective interest in the study of character that ever gained a temporary foothold, it seems proper to consider the nature of its pretensions and their following. Propagandists have an enviable if perilous vigor and enthusiasm—an element of reckless abandon not unrelated to the extravagances of mania in the exaggeration and self-deception which it entails. Lavater had the simpler problem of collecting drawings and engravings in imposing array to enforce the principles of physiognomy. Gall collected skulls and casts, and induced persons with marked mental peculiarities to have their heads shaven so that their replicas in plaster might be at his service. He asked that

> every kind of genius make me heir of his head. . . . Then indeed (I will answer for it with my own), we should see in ten years a splendid edifice for which at present I only collect materials.

The critical peril of false theories lies in their applications. Gall's interests seem to have remained for the most part scientific and objective; but in association with Spurzheim, whose direction of the phrenological movement largely determined its course, they took a more practical turn, and therein found their degradation. The extension of the phrenological principle to races and animals as a zoological problem appealed to Gall. He tells with ludicrous if pathetic simplicity of his baffling attempt to interpret the prominence of a part of the cranium which monkeys and women have in common. Finally,

> in a favorable disposition of mind, during the delivery of one of my lectures, I was struck with the extreme love that these animals have for their offspring. Impatient of comparing immediately the crania of male animals, in my collection, with all of those of females, I requested my class to leave me, and I found, in truth, that the same difference exists between the male and female of all animals, as existed between man and woman.

Thus was the cranial localization of "love of offspring" discovered.

Phrenology similarly offered the clue to racial differences.

> The foreheads of negroes are narrow, and their musical and mathematical talents are in general very limited. The Chinese are fond of colors, and have their eyebrows much vaulted. According to Blumenbach, the heads of the Calmucks are depressed from above, but very large laterally, about the organ which gives the inclination to acquire; and this nation's propensity to steal, etc., is admitted.

It was seriously set forth that the dog, the ape and the ox do not sing because the shape of their heads shows the absence of the faculties for music; that the thrush or the nightingale had heads with developed musical faculties, and the hawk and the owl lacked these parts; that in the male nightingale or mocking bird the head was square, angular, and more prominent above the eyes, while in the female these parts were conical, thus endowing the male and not the female with the gift of song. "Observe the narrow forehead of the dog, the ape, the badger, the horse, in comparison with the square forehead of man, and you will have the solution of the problem why these animals are neither musicians, nor painters, nor mathematicians." Extravagant as this may appear to our scientifically minded generation, it yet represents the more sober conclusions of men conversant with the science of the day. In the hands of system-mongers and quacks the doctrines were carried to far more capricious conclusions.

It was the practical tendency to read character and predict capacity or even career that was responsible for the rapid deterioration of phrenology. This course was set by Spurzheim, under whose influence phrenological societies were founded in England and America, and the world deluged with books, pamphlets, manuals, lessons, exhibitions, charts, plaster-casts, institutes, parlor talks and street demonstrations for the dissemination of character-reading by the bumps of the head—a movement, the waves of which still beat feebly along the remote frontiers of intellectual venture. An excursion into these disorderly by-paths—suggestive of the slums of psychology—would have little profit.[1] It would but indicate that slight deviations in principle lead to the widest divergence of result. An intellectual degradation ensues as the movement descends to lower strata—an issue not unlike the social degradation of sections of cities where questionable occupants inhabit the dwellings that sheltered the respectable citizens of other days. Though we

[1] The excursion would indeed serve to justify the general conclusion that the sporadic survival or revival of such systems as physiognomy, astrology, phrenology, palmistry, fortune-telling, dream-interpretation, etc., is due not to the appeal of their evidence, but to the persistence of the attraction of the occult as well as to the promise of practical revelation. For it is characteristic that this class of latter-day compendium upon "character" through the reading of heads, faces, hands, etc., combines and resurrects with curious ignorance of their source, with a strange insensitiveness to their mutually contradictory positions, all the varied by-paths of obscure and discredited lore which we have cursorily surveyed. Aristotle, Porta, Cardan, Lavater, Gall, Spurzheim reappear in doctrines, without assignment of source, in support of "systems" purporting to reveal the secrets of human nature for the small consideration of the purchase of the volume. The occult—representing poverty if not misery of mind—like misery, makes strange bed-fellows.

* By Prof. Joseph Jastrow, of the University of Wisconsin, in *The Popular Science Monthly*.

can not hold the founders responsbile for this issue, it is yet true that they prepared the way for it by their own practices. Gall and Spurzheim conducted tours in prisons and asylums, reading from the shapes of the heads of the inmates the propensity to forgery, theft, violence or lack of thrift which brought them to their fate. One prisoner showed the "organs of theft, murder, and benevolence all well developed, and, true to his organs, robbed an old woman and had the rope around her neck to strangle her, when his benevolence came to the surface," and prevented the fatality.

Such was the practical degeneration and such the fallacious principles by which phrenology attempted to oust physiology from its domain. At the time psychology was not sufficiently developed to assert its claim against the phrenological pretensions. Spurzheim had a stronger psychological bent than Gall, and developed an arbitrary psychology to fit the scheme. He distinguished between the emotional and the intellectual powers, dividing the former into *propensities*, which were direct impulses to action (like the desire to live, the tendency to fall in love, destructiveness), and *sentiments* which were complex human powers (like self-esteem, hope, mirthfulness, ideality); the latter were either *perceptive* (like size, tune, time), or *reflective* (like causality and comparison). This construction was distorted and confused, but yet not so strikingly divergent from other contributions as to arouse suspicion of its forced adjustment to the alleged findings. It was these latter, apparently substantiated by anatomical evidence, that kept the system alive. In the actual procedures of proof the simple psychology of self-deception was the dominant factor. Either the trait was marked and the phrenologist readily persuaded himself that the prominence—at best slight and not clearly defined—was present; or in the presence of a marked "bump," he was readily convinced that the required trait—as a rule a matter of uncertain and variable judgment—was conspicuous. As a contribution to the temptation that allegiance to theory offers to the self-deception in the determination of fact, the retrospective view of the subject has permanent value. Prepossession, though unrecognized by the phrenologists, is likewise a quality of human nature, with an interesting psychology of its own.[2]

[2] It is characteristic of the wave-like oscillations of movements of this kind that in periods after the desertion of the position by the scientific world, an occasional reaction appears and gains a considerable adherence. An Ethological Society, which publishes the *Ethological Journal*, was founded in 1903 and attempts to reinstate the phrenological position, though in a wholly modified form and with an attempt at reconciliation with the established localization of function in the brain; the latter is in a legitimate sense the new and true phrenology. There is no reason, except the historical one (which, however, is adequate), for giving the term phrenology any less respectable status than that of psychology itself. It is clear that the doctrine of the localization of function in the cortex of the brain represents a chapter in the development of physiology, which replaces the series of conjectural and extravagant views that belong to the antecedents of our subject. It should not be inferred that the Ethological Society is wholly devoted to this reinstatement of phrenology; it considers the entire range of topics bearing upon character and temperament, but presents a leaning towards the impressionistic and obscure interpretations. It may be added that so distinguished a contributor to the principles of modern evolution as Alfred Russel Wallace believed that the neglect of phrenology was one of the intellectual crimes of the nineteenth century, and maintained that this aspect of physiological and psychological research is central in its promise for the regulation of mental affairs in the future. The attempts to restate aspects of the phrenological position should be mentioned. They undertake a "Revival of Phrenology" and are represented by Hollander "The Mental Functions of the Brain" (1901).

Communicating With Aircraft

Various Methods of Signaling

There is probably no more difficult matter than to identify aircraft with certainty. How far-reaching this difficulty is cannot well be dwelt upon, but it is legitimate to put forward certain considerations in connection with it.

German aeroplanes are usually marked under their wings with a black iron cross; Allies' aeroplanes by a circular target of blue, white, and red, or black, white, and red. With a good glass these markings can be discovered against certain kinds of sky when the aeroplane happens to get enough light underneath it. As, however, there is nothing to prevent a German aeroplane from imitating our mark, it is clear that identification must be carried to a more reliable point. Wireless would no doubt enable the recipient of the password to admit the nationality of the aeroplane issuing such password, but it will take some time before troops can be warned that here is a friend and not a foe. It is small wonder, then, that flyers are exposed to more danger from their own side than they are from the enemy, since it is over their own side that they must daily descend to alight, bringing themselves closely within point-blank range. Our own flyers, owing to certain elaborate precautions, do not suffer much from friends' bullets, but it is well known that at the beginning of the war Russia, French, British, German, and Austrian aeronauts all suffered from the zeal of their own troops.

SIGNALING TO THE GROUND.

This brings in at once the matter of signaling from and to aircraft. Countless ways exist and offer more or less fractional solutions of the problem. Signaling from aircraft happens to be the easier, and also the more vital, of the two requirements, largely owing to the importance of directing artillery fire from the air, and to the fact that any aeroplane entrusted with discovering the answer to a specific inquiry to which yes or no is the reply, can give such a reply without alighting and proceed to its base.

Some of the systems of signal are as follows:

(1) Message bags, loaded and connected to long streamers, by which they may be found when on the ground, convey the maximum of information, maps, photographs, orders, requests, inquiries. They have the advantage of light weight and easy installation without mechanism, and with stable aeroplanes the messages can be written up by the pilot himself, and therefore a passenger is not needed. They have the drawback that the message once recorded may fall, either alone or with the stricken aeroplane and pilot, into enemy hands; they also involve a return home of the aeroplane to the place where the message is wanted.

(2) Wireless does not involve the return of the sender, and the message, being sent in code, does not reveal anything to the enemy. The drawbacks are the necessity for a prearranged receiving apparatus, the weight of the apparatus, the attendance required upon the accumulators, or the special fixtures to the aeroplane engine of a wireless generator or dynamo. Wireless can be worked by the pilot alone, it is true, but for all very accurate observations requiring immediate transmission it is probably better to employ an observer, who then does the sending. Special precautions to avoid setting fire to any gasoline leakage by the wireless spark or the dynamo or the sending switch are also required. The operator must know the Morse code, and this is not in the ken of all staff observers, though luckily it is easy to acquire.

(3) Signaling by means of lamps in the aeroplane requires two men in the aeroplane; it covers much the same results as wireless, but the range is more restricted in daylight and is adversely affected by the presence of clouds, above which it is very usual for observation flights to be made. Clouds below 6,000 feet are the rule, observation flights below 6,000 feet over the enemy are the exception. Morse, or a prearranged code, is used. "Overhearing" by the enemy is easily avoided by the use of a narrow beam.

(4) With the system of signaling by means of the Grubb reflector the aeroplane carries the reflector and requires a strong beam to be projected upon it from the ground. The signals are entirely secret, being reflected back to the sender and to him alone, and owing to the ingenious arrangement of the mirrors the flyer has no need to keep his reflector pointed at the person sending the beam of light. In this way it is possible to avoid using a passenger—and it must be remembered that the absence of a passenger and his equipment and armor means the saving of some 180 pounds of weight, and therefore, for the same engine power, a more quickly-climbing aeroplane. If a scout class of aeroplane is employed far greater speed, and therefore safety for the flyer, is secured than by either (2) or (3). This system is not comparable with (1), which subserves a totally different purpose.

(5) A system analogous to wireless is one employing sound. The source of sound may be the engine of the aeroplane, and its interruption by means of the switch serves for signaling. Special apparatus on the ground is needed for listening as well as for following the course of the particular aeroplane listened to. It is possible by code to avoid "overhearing"—if, indeed, any overhearing can be effected except by appropriate apparatus. The range in distance of this method is one of its limitations, but its chief limitation is the interference due to very powerful sounds of guns, etc.

(6) A prearranged method of flying forms a very simple and effective mode of signaling requiring no apparatus and no passenger. Repeated dips of the aeroplane, circling, and banking according to code, convey the information. A defect is that an attack by enemy aircraft interrupts the signaling, whereas the completion of a message which is being sent by wirelss or by lamp signals or by reflector signals can proceed while enemy aircraft are being pursued, or, if needs be, fled from. A prearranged mode of flight may be a useful means of securely passing over one's own lines without being fired on—up to such time as the enemy detects the code and attempts to copy it. Even against this there is easy defense in a sufficiently frequent change of the countersign.

(7) Smoke signals, such as have been beautifully presented to the public in photographs by the French journal *Illustration*, have also their value on certain days. A good deal of apparatus is required owing to the large amount of smoke-producing material needed to cause a dense enough cloud. The air speed of the aeroplane and the slip stream of the airscrew tend to scatter the smoke puff unless it be very dense. Code is necessary for secrecy and the system is more suited to airships when floating with and in the wind.

(8) The plan of extending large disks on one or other side of the aeroplane has been tried, but they are not easy to use for any considerable distance. Disks large enough to be visible are so large that their rapid obscuring is difficult, and moreover when extended they are liable seriously to interfere with the aeroplane.

(9) Colored fires, such as are projected from a small firework pistol, may be very useful for signaling gun fire, though they suffer from the drawback of being slow in use and requiring for a powerful light cartridges of considerable size, a number of which mount up to a considerable weight. They can, however, be used by the pilot alone.

SIGNALING FROM THE GROUND.

Signals from the ground to the aeroplane are of importance also. The simplest plans deal with indicating a position in which a friendly aeroplane may alight by laying out a long strip of white canvas. This may also be so marked at one end as to indicate the direction of the wind, or to convey some simple message, such as yes or no. Groups of colored lights serve the same purpose, as also does a beam projected upon the aircraft and interrupted in Morse code, this being the converse of (3). Wireless is also used, and when receiving gear is arranged on the aeroplane very complete and satisfactory results are obtained up to a considerable range. To "call up" the attention of an aeroplane overhead, to which it is desired to speak, special fires can be directed by artillery to make a light ahead of the machine. A fast scout may be sent up to overhaul any aeroplane that must be called back, and a system of signaling by lamp patterns switched on and off also exists between aeroplane and aeroplane.

There are other methods which, since completeness is always the chief attraction of such a summary as this, it is regrettable, cannot be discussed at present. Nevertheless enough has been said to remove the too common idea that wireless—usually supposed to be of a very feeble sort—is all that airmen have to rely on for communication once they have plunged alone into the vault of heaven.—*London Times Engineering Supplement.*

Determining the Depth of a Foreign Substance in the Body

While the ordinary radioscopic method plainly shows the horizontal location of a foreign substance in the human body, such as a bullet, the vertical location, or the depth, is not indicated. By a simple system, described by Hirtz and Gallot in *Comptes Rendus*, the depth of a bullet can also be accurately located. A Roentgen tube is placed under the patient, who lies on a table, and the screen is so arranged above the patient that the shadow of the bullet falls upon its center. The position of this point is marked on the skin of the patient with a pencil. The tube is now displaced horizontally in any direction, and another shadow point located on the screen. A special apparatus allows the screen to be raised and again lowered into exactly the same position; while the screen is raised the patient is removed from the table. The screen being again in position and the tube still in its last position, a small ball of lead attached to a thread is lowered through the hole in the screen. The tube is then operated, and the ball is raised or lowered until its shadow coincides exactly with the second point originally located on the screen. The distance from the screen to this ball indicates the depth of the bullet in the patient.

The Progress of Surgery*

As Shown by Military Medical Service in Ancient Times

THE importance of military medical service was recognized in very ancient times. Long before medical science was founded by Hippocrates, Homer's Iliad records the presence of two physicians at the siege of Troy. These physicians, however, were also the commanders of a fleet of transports. Lycurgus (ninth century B. C.) assigns army surgeons to the same tents with soothsayers, flute-players and troop commanders. Xenophon (401 B. C.) in his narrative of the retreat of the Ten Thousand says that he was compelled to distribute his sick and wounded among several villages and that he left eight physicians with them. He adds that the private hospitals established in Greek cities received and cared for wounded enemies, but that the Romans restricted their attention to their own troops. During the Roman wars in Italy the legions appear to have had neither physicians nor surgeons. The soldiers were furnished with bandages with which they dressed each other's wounds. At Rome until the time of Julius Cæsar, physicians, who were generally Greeks or freed slaves, were held in little esteem. Cæsar admitted physicians to citizenship, but he does not mention them in his "Commentaries," and other ancient historians are almost as silent on this subject.

Fig. 1.—Machaon dressing the wound of Philoctetus.

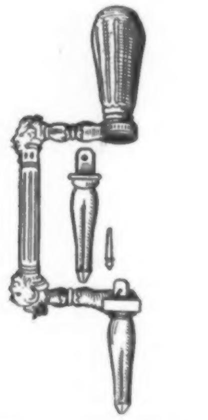


Fig. 3.—Trepan by Paré.

When Augustus established standing armies, they included a regular medical service, and a similar service was adopted in the navy.

Onesander, a Greek military writer of the first century, says that surgeons follow armies for the purpose of healing wounds, but Galen (131-201 A. D.) likens the anatomical knowledge of army surgeons to that of butchers.

The Roman historians of the Empire extol the solicitude of the imperial commanders for their wounded, at whose disposal Tiberius placed his personal carriages, litters and physicians. Trajan once gave his garments for making bandages. Germanicus, Hadrian and Alexander Severus were equally attentive.

A regular ambulance service is first mentioned in the sixth century. The emperor Mauritius (582-602) organized a corps of horsemen to carry wounded from the field, offering a bounty for each man rescued. The emperor Leo (886-911) greatly developed this service.

With the incursion of the barbarians all sanitary service disappeared and army surgeons are not mentioned during the Middle Ages.

In 1536 a great reform in the treatment of gunshot wounds was made by Ambroise Paré, the father of French surgery. For some inscrutable reason such wounds had previously been regarded as infected, and therefore in need of cauterization with boiling oil or water. Once, in the absence of these antiseptics, Paré simply dressed some wounds without cauterizing them, and on the following day he was agreeably surprised to find them in better condition than wounds that had been treated with boiling oil. Thenceforth he abandoned and opposed the barbarous practice. Soon afterward he devised the ligature of arteries as a substitute for cauterization after the amputation of limbs.

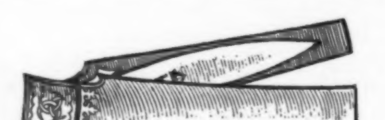


Fig. 2.—Lancet of A. Paré.

Fig. 5.—Dry suture of Paré. A strip of cloth is pasted on each side of the wound, and these strips sewn together.

Bold and successful methods of treating wounds of the head and brain lesions were adopted by Bérenger de Carpi a little earlier.

The advancement of the healing art, however, was slow and many queer remedies were employed, such as broths made of vipers and frogs, which are mentioned in a medical treatise published in 1778.

Throughout the Napoleonic period military medicine and surgery were well represented by Des Genettes and Larrey, who were also the historians of the expedition to Egypt. Here they established a regular, though imperfect, sanitary service. Ambulances were employed in the battle of the Pyramids, and hospitals were established at Cairo, Jaffa and elsewhere for the care of the wounded and of soldiers suffering with ophthalmia, dysentery and the plague. To the Cairo hospital was attached a school of practical surgery for the instruction of young army surgeons. By Napoleon's order, military bands played lively and inspiring airs before the hospitals every day at noon. The wounded were transported on horses or camels, in the latter case in cradles slung on each side of the animal's hump.

Fig. 4.—Twisted Suture of A. Paré.

Des Genettes vigorously combated the plague, which cast its black shadow over the whole expedition.

Gen. Marbot has described the heroic treatment applied to his foot, in which gangrene had developed after it had been frozen on the battlefield of Eylau. He was held by four men while the surgeon cut out the gangrened parts as if he were removing decayed portions of an apple. The surgeon then mounted a chair, saturated a sponge with hot sweetened wine and let the liquid fall, drop by drop, into the hole which he had excavated. The pain was excruciating, and the general had to endure it every morning and night for a week, but his leg was saved.

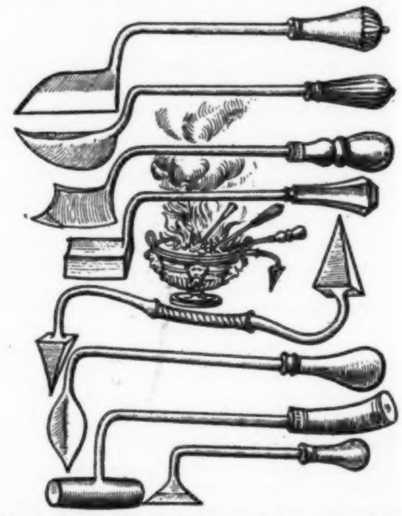


Fig. 6.—Cauterizing implements used by Paré.

In the Crimean war 75,000 of the French army of 300,000 men died of anthrax, scurvy, typhus and hos-

* Abstract of Norbert Lallié's article in *La Nature*. Translated for the SCIENTIFIC AMERICAN SUPPLEMENT.

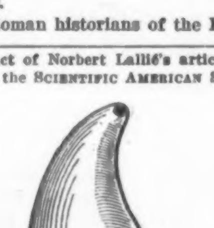


Fig. 7.—Cupping vessel exhausted by sucking. Used by Anbroise Paré.

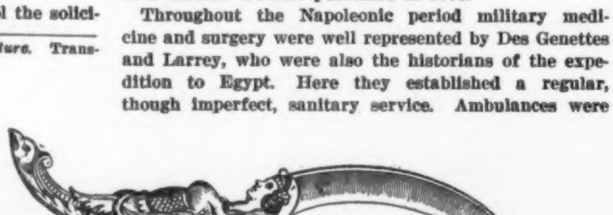


Fig. 8.—Bistoury used by Paré.

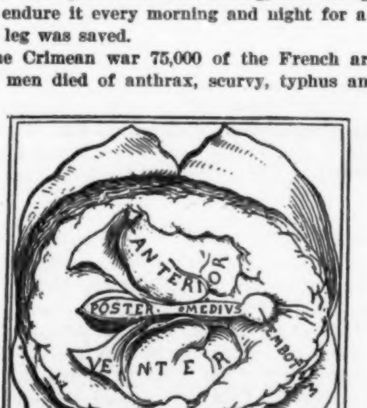


Fig. 10.—The brain, as represented by Bérenger de Carpi.

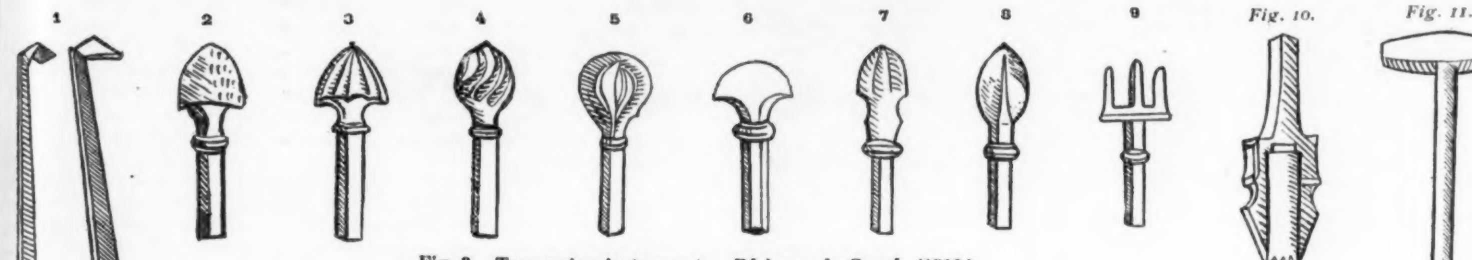


Fig. 9.—Trepanning instruments. Béringer de Carpé. (1518.)

pital infection. Death followed 91 per cent of amputations of the thigh and 55 per cent of amputations of the arm. The physicians and surgeons did their best, but they were too few, and the organization and equipment were defective. In May, 1855, there were only 78 ambulance and field hospital surgeons for an army of 108,000 men. Similar conditions prevailed in the Italian campaign (1859-1860). At Magenta each ambulance surgeon had 175 wounded men to care for. At Solferino each surgeon had 500 patients, so that even if he were able to work twenty hours continuously, he could not give three minutes to each patient.

The Crimean and Italian campaigns proved the necessity of a radical change in military surgery. This transformation has gradually been accomplished, both in the administrative and in the medical and surgical fields. The railway and the automobile have facilitated the transport of the wounded and ameliorated its attendant conditions. Antiseptic methods have greatly

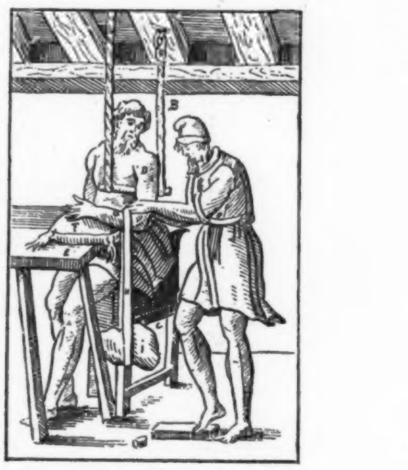


Fig. 11.—Setting a broken arm.

diminished mortality and hastened cure. In large armies, however, the wounded may still, at times, be too numerous to be properly treated.

Important progress has been made during the present war, but still further improvement is required. The ratio of dead to wounded has been reduced from one third to one fifth.

A soldier represents a capital, a value, a force. His death or illness is a loss for the whole nation. For these as well as for humanitarian reasons it is imperative to neglect no means of restoring to health the citizen who has risked his life in defense of his country.

Fig. 12.—Treatment of fracture (seventeenth century).

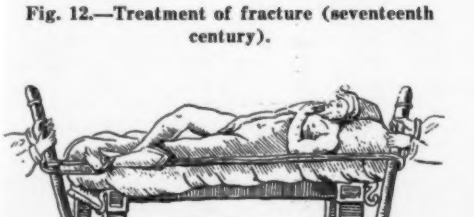


Fig. 13.—Extension and contra-extension of the leg.

Trench Frost-Bite*

During the winter of 1914–15 a large number of soldiers fighting in the trenches in Flanders became disabled from the effects of cold on their feet. The condition is to be distinguished from true frost-bite in which very severe cold causes necrosis of the tissues. In cases of trench frost-bite necrosis may occur, but it is not frequent, and the characteristic symptoms are swelling, pain, and disturbance of sensation in the feet.

A considerable amount of investigation has been carried out on true frost-bite, but less attention has been paid to the effects of moderate cold on the feet of the soldiers in the trenches. Our inquiry consisted of two parts: (1) The observation of the clinical condition of a number of cases which were under treatment in the military hospitals in Edinburgh; and (2) a study of the effect on rabbits' feet of conditions similar to those to which the soldiers were subjected.

In the medical records of modern campaigns, accounts of trench frost-bite are frequently to be found. Larrey's (1812) description of the effects of cold in Napoleon's Russian campaign in 1812 shows that he was familiar with the condition. In the history of the Crimean War it is cited that cases occurred when the temperature was above the freezing point, especially when there was rain and a cold northeast wind with frost at night. Other mission to Thibet in 1903, and again in the Balkans in 1913 by Weiting (1913) and by Page (1914).

In all these campaigns the condition was associated with prolonged exposure of the feet to a moderate degree of cold while at the same time they were immersed in water or mud. That the condition was the result of direct exposure to cold was shown from the fact that the severity of the lesion was determined by the extent to which it had penetrated from the surface. Yet it differed essentially from the frost-bite due to exposure to severe cold; as a rule, the parts affected did not after a short time become dead beyond hope of recovery, and the face and hands usually escaped.

The following practical considerations are suggested by the foregoing investigation. The main efforts must be directed toward prevention. As the condition is one of damage to tissues, once it has been established, recovery can only take place after a prolonged process of regeneration.

1. The soldiers should practice massage on their feet before going to the trenches. There is some evidence to show that persistent rubbing of the feet beforehand has enabled the men to escape to a considerable extent the effects of exposure to cold.

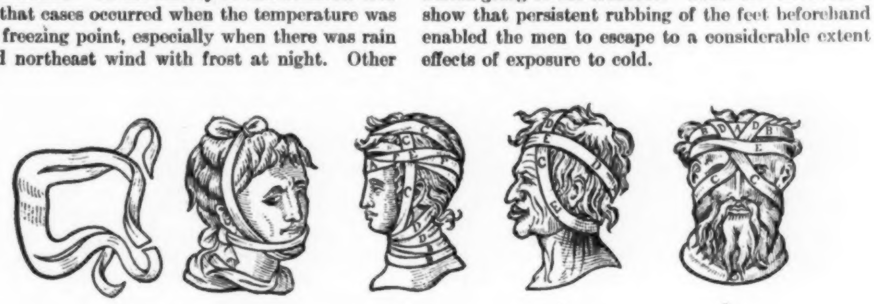


Fig. 14.—Chin supports and head bandages (eighteenth century).

factors which helped to bring about the condition were lack of opportunity for changing the clothes, tight boots, fatigue, defective nutrition, and diseases such as scurvy or fever. In the later stages of the Crimean campaign, conditions were much improved and trench frost-bite became much less frequent and was then usually associated with exposure to extreme cold. Similar cases of frost-bite were described by Davys (1904) and Powell Connor (1904) among the members of the British

Fig. 16.—Costume of physicians attending the plague stricken (1721).

2. A study of the cases shows that the symptoms begin to be felt, as a rule, after 48 hours' exposure. It is clear, therefore, that to shorten the time in the trenches would be the most essential measure of prevention.

3. While men who have been exposed to the conditions causing frost-bite without having been affected are resting between their turns of trench duty, they should persistently practice massage of their feet twice daily.

4. Careful attention should be given to anything which may constrict the blood-vessels. Constriction by boots and puttees should be avoided. Loose moleskin leggings would probably be found more suitable than puttees, as they would provide warmth without constriction. The advantage of leggings is that they provide the protection of an ample cushion of air and they drain more

Fig. 15.—Field ambulance service (eighteenth century).

readily than compact wrappings, the existence of a non-conducting air cushion being thus re-established. The soldiers wear boots of a large size, but they have a practice of putting on two pairs of socks, and this probably tends to a certain amount of constriction. It was observed that the excoriations were situated on the outer and inner borders of the feet, and this fact suggests that some degree of constriction existed. It is significant that the parts most liable to trench frost-bite are the parts where under ordinary circumstances callosities and

* Notes from an Article by Lorrain Smith, M.D Edin., F.R.S., Professor of Pathology, Univ. of Edinburgh; James Ritchie, M.D. Oxon., Professor of Bacteriology, Uni. of Edinburgh; and James Dawson., Neurological Histologist, Laboratory of the Royal College of Physicians of Edinburgh, published in The Lancet.

corns are most frequent. The question arises whether the upper leather of the boots could be made more pliable without diminishing the stability of the sole or of the boot generally. The soldiers very commonly cover their feet with oil and derive benefit from this. There may be several advantages in this. Among other effects it will act as a bad conductor of heat; it may minimize the effect of the wet; it may keep the leather of the boots more pliable and its application may be the occasion of a thorough massaging of the feet. In order to obtain the full effect the oil should be of high boiling point and be used in considerable quantity; semi-solid oils such as vaseline would probably give the best results.

5. To maintain the circulation in the feet it would be helpful to increase the clothing of the legs. This might be done by using leggings reaching the thigh or by wearing two pairs of pants.

6. It is found that the onset of the symptoms was gradual, as a rule. A soldier would at the end of a turn in the trench suffer from slight swelling. During the resting period he recovered, but on the next occasion the symptoms became so severe that he was disabled. Such cases should be investigated by the medical staff and tested before they are allowed to return to trench duty.

7. The period of commencing recovery. When the condition has become so severe as to disable the soldier he should not be allowed to walk or march more than is absolutely necessary when he leaves the trench. As soon as possible he should be conveyed to a resting place. In many cases the records tell of disabled men having to walk back to billets some miles behind the line of the trenches. Wherever possible in such circumstances transport should be taken advantage of to avoid unnecessary pain.

8. When the billets are reached measures should be directed to giving the feet as much rest as possible. The feet should not be warmed in any way that causes congestion, and the return of the normal circulation should be delayed rather than hastened.

Massage in the After-Treatment of the Wounded*

Propor Methods for Removing Stiffness in Joints

For some months past reports have, with varying frequency, reached me, the tendency of which is to show that all is not as well as it might be with the after-treatment of some of our wounded, so far as that consists of massage.

My evidence compels me to the opinion that a very real evil exists; and I am anxious to do what I can to draw to it the attention of those surgeons whose good work is being undone by injudicious after-treatment, to explain its origin, and to venture a suggestion by way of remedy. The evil originates partly in ignorance and partly in misconception. The masseur arrives at the bedside, or receives his patient elsewhere labeled "Massage required for this case." He finds, let us say, a scar on a limb and one or more joints quite stiff, and the patient complains of pain—perhaps constant, perhaps only on attempted movement. The masseur then elicits what information he can from his patient, which usually amounts to the date of wound and of operation, if any. He can learn little or nothing as to what tissues were injured or what was done at the operation, unless he has the good fortune to find a radiograph to help him. Even this is of doubtful service seeing that the masseur is no X ray expert. He thus learns little or nothing of what has happened, and can only surmise that the joints are to be bent or straightened. He does not know—usually it is impossible for him to discover—how far either movement may be impossible owing to anatomical injury or deficiency. And let us remember in further extenuation that the masseur is not a diagnostician to distinguish, let us say, a neurosis from a traumatic neuritis, or symptoms due to the severance of a nerve from those subsequent to extensive operation for tendon suture. Hence he guesses at the task which he believes that his surgeon has set him, tackles the obvious cause of disability, and seeks to obtain movement in all joints that lack it, to the limit either of his ability or of the endurance of his patient.

The misconception under which the masseur usually labors is that stiffness is due to the presence of adhesions, which it is his duty to "break down." But here is no part of the work of the masseur; it is the surgeon's work and is performed by him—under an anesthetic if necessary. Thus, when a patient is recommended for massage there are (or should be) no adhesions in the joints capable of being "broken down." Limitation of movement may be due to anatomical defect; if so, the masseur should be informed. It may be due to the contraction of a scar, of muscles, of ligaments, of tendons, or to a general matting together of the soft parts. No amount of sudden stretching or pulling can effect a cure of any of these conditions. Progress must be slow, and the more gently the treatment is performed the more rapid will be the result. Nature has ordained that the most rapid and perfect method of curing an injured limb is to restore its function, and, if use is possible, the more it is used the quicker will be the cure. If the limb is subjected to treatment that causes pain, some period of time during which it might have been in use is wasted by the necessity of keeping it at rest while the pain passes off. Thus the dose of movement given daily should be the maximum that does not cause more than a transitory twinge. If painless movement is impossible, it is the masseur's duty to attempt so to relieve the irritability of the nerves, or so to manipulate the soft parts, that he may be able on a subsequent occasion to give his first dose of painless passive movement. A little later he can prescribe ever-increasing doses of painless active movement.

Then, again, the disability may be due to what we can only describe as the "functional joint." By this is meant a joint in a limb which, having received injury, is found on examination to be rigid, but which is possessed of perfect function when the patient has been anesthetized, the rigidity returning as the anesthesia passes off. Here we have a local evidence of traumatic neurasthenia—it has been called hysterical, but if this be the nature of the trouble (which is particularly common in childhood) it is often the only evidence of hysteria that the patient will exhibit in a lifetime—and any measure that causes the faintest trace of discomfort (to say nothing of actual pain) can only aggravate the disability. The same applies whenever pain or disability is due to the fact that a nerve-trunk has been bruised or otherwise injured.

When we commence our massage treatment it is essential to remember the general condition of our patients. They may have been in the fighting line for months, and have probably passed through a time of superhuman fatigue and strain. They have been wounded, have probably undergone operation, and many have suffered from septic absorption. Last, but not least, after months of severe physical exercise and training, they are suddenly deprived of any exercise whatever. Small wonder, then, if neurasthenia should be present. And it would surely be better to choose a treatment for their injured limbs that has been proved devoid of pain (even supposing it to be a trifle slower in restoring the use of the limb, which in fact it is not) in preference to one that, by causing suffering, can only prolong and perhaps accentuate the neurasthenic tendency.

Let us now consider briefly the nature of the treatment calculated to restore an injured limb most rapidly. It is common experience that pain and disability go hand in hand. Hence our first duty is to combat pain, and I must, as elsewhere,[1] invoke the name of the late Just Lucas-Championnière as my authority in attempting to describe the treatment that should be administered.

There are three main laws which should govern all massage treatment for a recent injury. They are: 1. Only the most gentle movements possible are to be performed; any irritating (so-called stimulating) movements are prohibited. 2. Any point that is tender or hypersensitive is the last that should receive attention, and the site of wound or fracture must be scrupulously avoided through all the earlier stages of treatment, and especially until normal sensation has been restored. 3. The actual nature of the massage movement that is performed is of minor importance, but it is essential that it should be slow, and gentle, and rhythmical.

Massage treatment on these lines will soon be found to allay any irritability that may exist in the nerve supply of the limb, and as soon as this has been accomplished the dose of mobilization may be administered. Here the rule must be "little and often," remembering that repeated movements of small amplitude lead to the restoration of a limb far more rapidly than any attempt at free movement; that will follow spontaneously without pain or suffering of any sort if only we will have patience. The movements should be slow as well as of small amplitude, often repeated, and *free from pain.*

As soon as the patient is able to do so, he should begin to exercise each joint in turn; he will be able to do so only if he has escaped suffering during his dose of passive movement. The laws that govern the administration of passive movements apply equally to that of the active movements. As soon as the patient can exercise his joints himself the masseur should begin to administer a dose of resistive exercises, and he may also for the first time allow himself to knead the limb. This should be done gently and slowly, any vigorous or rapid movements being a great mistake, and of course unscientific. Each *seance* should terminate with a dose of the smooth, gentle, rhythmical stroking. From this point onward the patient can benefit enormously by the judicious use of the faradic current, which may replace massage treatment entirely or in part. Nothing here said, it should be remarked in passing, must be taken as depreciating the great importance rightly attached to electro-therapy.

Immediately the patient is able to make use of mechanical appliances without pain he may almost be left to take care of himself, except in so far as it may be necessary to assist the return of muscular power by the use of the electric current. All that is necessary is to encourage use or check over-use, as the case may be. The dose of exercise may cause a little aching in the limb, but the patient can be told that he may persevere, provided that no œdema follows use and that any pain is relieved entirely within half an hour of the limb being placed at rest. The value of resistive exercises is not, it appears, sufficiently realized; a few minutes of these exercises will restore painlessly far more movement than can ever be obtained by using violence. Moreover, the benefit is lasting.

As regards the number of patients that should be allotted to each masseur, the treatment advocated will allow of his dealing fully and efficiently with five or six cases in two hours, or, if some of them are approaching convalescence, perhaps as many as ten.

By use of the treatment thus briefly indicated the patient will mend as rapidly and as thoroughly as the nature of his injuries permits. He will recover from present pain, he will suffer not at all under treatment, he will sleep better, and any neurasthenic feature will be obliterated by the most efficient method at our disposal.

The means for the complete attainment of this end would be the direct supervision of the work of every masseur by a medical man who has had first hand experience of the principles and practice of massage and general mechano-therapeutical treatment. This ideal being unattainable because the number of those who have had the necessary experience is limited, some such scheme as the following might possibly be adopted with advantage: 1. A surgeon who recommends a case for massage might make a point of seeing that full information as to what has taken place is conveyed to the masseur. 2. If he can then arrange to examine and question his patient at intervals both as to his progress and treatment, he will at least be able to satisfy himself that no injury is being done. 3. No masseur or masseuse should be allowed to work "on his (or her) own." It should be possible to arrange that in every centre there shall be someone whose sole duty is that of "go-between" from surgeon to masseur, who will prescribe treatment, supervise its administration, and constantly watch the patient's progress. It should usually be practicable to select for this duty someone who has received full training as a nurse in England before she commenced to study massage. Insistence on this qualification would do much to avoid one danger. Training as a nurse inculcates the instinct which is so valuable an asset in the treatment of all forms of recent injury—the prevention and relief of suffering. It will serve to counteract the teaching that may have been received in the massage school that pain and discomfort are inseparable from successful treatment, that "massage become painless ceases to be massage and is merely treatment by suggestion," and that the duty of the operator is to give the patient "all he can stand." It would seldom be wise, in my opinion, to entrust such a task to anyone who had received foreign training in massage. Except in certain schools in France, and in rare instances elsewhere on the Continent, the massage taught is too violent to be applicable to recent injury.

Unless some steps are taken in the direction indicated, it is feared that in many a case the success of the surgeon's work will still be in jeopardy, and unnecessary suffering still be inflicted.

*By James B. Mennell, M.D., in the *Lancet.*

[1] "Treatment of Fractures by Mobilization and Massage," *passim.*

Economizing Coal in Gas Making

At a large gas plant in Holland the experiment has been tried of mixing peat with the coal with excellent results. The quality of the gas is satisfactory, and a considerable saving of coal is effected. The charge for the retorts is made up of two parts by weight of coal and one of peat; the peat is entirely consumed, so there are no by-products. It was found that if peat alone was used the retorts became overheated, because of the steam resulting from the moisture that is always present in peat.

Faulty Fabrics*

As Viewed by the Laundryman

By W. H. Johnstone

In considering the subject of "Faulty Fabrics," I think it is necessary that we should take a careful survey of the various processes the cotton has to pass through before cloth is made. We shall then discover the effect of certain irregularities in each department. These in themselves may appear to be of very little consequence to the worker concerned, but are really serious from the laundryowner's point of view.

When the cotton crops have been gathered the cotton is taken to what is known as the "cotton-seed opener." Thus machine disentangles the seed cotton, which is more or less matted together, thus preparing it for the next process, the "ginning." The object of the ginning process is to remove the seeds and husks from the cotton, previous to its being made up into bales ready for export to the various cotton markets of the world.

We now come to the processes with which some of you may be familiar, but I think it is necessary that we should consider them in passing.

When the spinner has decided on the grades of cotton to use for his various "mixings," the bales are taken to the "bale breaker," where they are opened, and the cotton is partially cleaned before it passes on to the "cotton mixer." If it is not required to mix it with any other quality of cotton, it is passed to the "scutcher," where it is again cleaned and formed into "laps," and it is of the greatest importance that these laps are of uniform weight and density. From the scutcher it passes on to the "carder." The object of this machine is to arrange the fibers of the cotton approximately parallel, removing at the same time unripe seeds or other impurities that may be left in the cotton. From this machine it is delivered into cans in the form of "sliver." These slivers are next passed on to the "drawing frame," where several of them, according to the quality of the cotton used, are blended together, thus forming one long sliver.

From the drawing frame the slivers are next passed on to the "slubbing frames," where the first "twist" to the threads is given, after which it is wound on to either bobbins or tubes. These bobbins or tubes are passed on to the "roving frame," where more "twist" is given to the cotton. It is now ready to be spun into either "twist" or "weft," whichever the spinner is making, and this is done on the ring spinning mill or "mule."

It is very important that the spinner should be very careful in choosing the cotton for his mixings and that the manufacturer should also be ever mindful that the spinner supplies him with the correct qualities of yarn.

DIFFERENCES IN CLOTH.

I think we should now consider the various cloths, such as longcloth (muslin), lawns, nainsooks, muslins, etc., as these are the principal ones that we have to deal with and are only of a plain weave.

When the manufacturer receives an inquiry, unless the order is for a "repeat," he generally receives a piece of cloth as a sample upon which to base his quotation. On many occasions he is asked to give a cloth of a stipulated weight to the width and length stated. It is when these stipulated weights are to be given, that the difficulties of the manufacturer begin. He calculates the weight of yarn to make the cloth required, but should these not give the weight necessary he has to size the "twist" in order to make up the difference. The ingredients to be used for the weighting vary according to the cloths, and will be dealt with under the heading of sizing.

It is of great importance in making the various cloths, that the right quality of yarn is used. For instance, for a longcloth of ordinary grades, American yarn only is necessary, but when we come to fine lawns, nainsooks, etc., it is necessary to use Egyptian yarn.

When the manufacturer receives an order he covers it by buying sufficient yarn to complete it. The twist, or the yarn, is those threads which constitute the length way of the cloth, and is bought from the spinner, generally in the form of cops. After being tested to see that it is the correct strength, that is to say, that it pulls a certain weight to the lea of 120 yards, it is passed on to the "winder," who transfers the thread from the cops to the "warper's" bobbin. Winding is a very important process. One of the faults which occur here is caused by threads breaking, and if they are carelessly pieced (in several of the large cotton mills the "Barber knitter" and other knot-tying appliances do this work far better than the winder can do it by hand), trouble will result in the subsequent stages of manufacture, causing defects in the finished cloth. From the winding machines the bobbins are passed on to the "warper," whose work is to make the beams, which contain, say, 500 threads. A certain number of these beams make up what is known as the "weaver's" beam.

The warping mill is supplied with a very ingenious mechanism, which stops the machine automatically upon the breakage of one single thread. As there are hundreds of threads, and breakages are very frequent, it is very apparent how useful this invention is. The warper has to piece the end of breakage before the machine is set in action again.

SIZING PROCESSES.

When a sufficient number of the warper's beams are made, these constitute what is known as a "taper's set," and the next process is to gather the whole of the threads (sometimes numbering from 3,000 to 4,000 on one beam) and size them. This work is done on the slashing and tape sizing machine. This sizing process is very necessary, as without some preparation in this manner the threads would not stand the strain of the actual weaving.

The ingredients to be used in the size vary according to the different cloths. For instance, a cloth that has to be bleached before it is put on to the market, only requires what is known as "pure size," and that is about 10 to 15 per cent.

A considerable variety of substances are used in the size mixings, each of which has a specific work to do. They are divided approximately as follows:

1. Substances which possess adhesive properties to strengthen the yarn and to fix other ingredients and any loosely projecting fibers on its surface. These include wheat and sago, flour, starches, etc.
2. Substances to render the yarn soft, pliable, and smooth, such as tallow, grease, oils, etc.
3. Weighting substances, such as china clay, French chalk, etc.
4. Ingredients to destroy or prevent the growth of mildew. Zinc chloride is principally used for this purpose.
5. Deliquescent substances which attract moisture to the threads to render them more pliable in the weaving process, and also to prevent the size from being rubbed off the yarn. These include magnesium chloride, glycerine, etc.

In order to better understand the mixing of these ingredients for size-making, I may state that the following are practically standard mixings:

1. For a pure size wheat or sago flour, tallow and water.
2. For a 50 per cent size wheat flour, china clay, tallow, magnesium chloride, zinc chloride and water.

You will quite see from these two mixings that if we have to deal with cloth that has been subjected to the size mixing as given in No. 1 we should not have very much trouble, but, unfortunately, we have to deal with cloths which have been sized by ingredients as enumerated in No. 2.

After the sizing process, the weaver's beams are passed on to the "drawer in," whose work, when plain cloth is being manufactured, is to draw the threads through what is known as "the healds." There are four of these healds to a set, and the threads are drawn through alternately as 1, 3, 2, 4, so that when the beam is put into the loom and "gaited up" the healds are lifted 1 and 2 together and 3 and 4 together, thus making each alternate thread lifted at the same time, so that when the shuttle passes through, the weft is interwoven with the twist, thus forming the cloth. You may, perhaps, wonder why I lay so much stress on this point, but you will easily see that if they are not drawn in correctly, instead of making a nice, even cloth the threads will be in twos, threes, and fives, and consequently, holes will soon appear in the process of washing.

WEAVING THE CLOTH.

This work having been completed, the beam is now ready for the final process of manufacture, that is, weaving.

There are several important facts which tend to make cloth weave well. Atmospheric conditions have a great deal to do with good weaving; for instance, on a very windy day, the threads are much more liable to break than on a nice fine day, and if the air in the weaving shed is too dry, the threads are apt to snap through insufficient moisture, which would render them pliable. Yarn that has been treated with size deficient in "softeners" will snap because it is too brittle, and on the other hand, if there has been too much "softeners" in th size the yarn will be too soft and will not stand the strain of the weaving, consequently the threads are very often broken.

All these breakages of the warp threads means that there is a tendency for holes to come in the cloth very soon after it is put into use, as the threads do not always break in ones and twos, but sometimes two or three dozen will break at once, and the result is what is commonly known as a "weaver's smash."

I will now ask you to examine some of the cloths I have here, but before doing so I want you to particularly understand that these are only brought to show some of the faults previously mentioned, and have not been bought as perfect cloth. I think after examining them you will form a better idea of the kind of faults I have been speaking of, and I hope, as a result, we shall gain some little knowledge that may be of help to us when dealing with claims that arise with every laundryman.

(Samples of cloth were then passed round and examined.)

After examining these cloths, although some of the faults contained in them appear very slight, I think you will admit that if they were put upon the market and made up into garments, some laundry would have trouble.

This cloth having been woven is delivered to the merchant, some of it in the "loom" state (unbleached), but a great deal of it requires bleaching before doing so. This is another process I think we ought to give some attention to, as we are often blamed for bad work.

LAUNDERER'S PERILS.

The thought has often occurred to me that while the cloth is going through the bleaching process it is sometimes "tendered" to such an extent that when it is put into use and has been washed several times these defects appear and the laundryowner is blamed for having damaged a cloth.

When the laundry receives a complaint from a customer about holes in garments he sometimes sends these articles to London to be examined by an expert and the following is a typical report to many of these questions:

"No injurious substances are actually present, but chemical tests upon the fibers show very distinctly that they have been injured at some time or other, by the use of excess of bleach or some other oxidizing agent. This appears to be the cause of the holes, although it does not follow that over-bleaching has happened recently."

I have often noticed when examining cloth a very strong smell of chloride of lime. This would give one the impression, without having tested for it, that there is still a certain amount of lime left in the cloth, and as you know, should this be the case, constant if slow tendering would be the result, with consequent trouble when the goods came to be washed. I think if we were to test some of the bleached cloths before they were washed we should be surprised at the results of our investigation.

I have also noticed, particularly on the heavier bleached cloths, that they split up near the selvedges. This is the result of the bleacher having to pull the cloth out to the desired width after bleaching, and I am of opinion that some of the table-cloths that give way near the selvedges are caused in this way.

COSTLY "CHEAP" BARGAINS.

There is another point of view we must look at when considering this question of faulty fabrics, and that is the "fent" trade.

Every manufacturer, however good he may be, has what is known as seconds or pieces of faulty cloth that cannot be sent along to the merchant with the bulk of the goods. These seconds are kept back and are sometimes sold to the clothiers very cheaply, who make them up into various garments, covering up as well as possible any defect there may be in the cloth. The clothiers overlook some of the faults so long as they get the cloth cheaply enough, but when these articles come to be washed and the defects show up more clearly, the laundry is blamed for damaging the articles.

Before concluding I would like to call attention to another very important matter, and that is faulty workmanship in making up the various garments that we have to deal with at the laundry

* A paper read before an English laundryowners' association.

A Simple Viscometer

According to the *Engineer*, a simple form of viscometer has been devised by Mr. Alan Speedy. It consists of a glass tube, of which a portion is drawn out into a capillary, which is then bent into a U. A sufficient length of the tube to cover the U completely is set vertically in the heating liquid. A small quantity of the material to be tested is filtered into the tube and allowed to reach the same level in both limbs. It is then sucked up to a mark in one limb, and the time it takes to fall a fixed distance is carefully measured. The results obtained with this simple appliance agree very closely with those given by the Dunstan apparatus.

Mount Rundle at Banff, showing monoclinal structure with escarpment on the face typical of the eastern ranges of the Rocky Mountains.

A scene in Yoho Park, Mount Stephen on the right and Cathedral Mountain on the left, taken from Burgess Pass.

Parks in the Canadian Cordillera*

Physical Features and Attractions in the Canadian National Playgrounds

By John A. Allan

CANADA set aside her first mountain reserve for the benefit and pleasure of the people in 1887. To-day there are eight national playgrounds in the Canadian Cordillera between the Great Plains and the Pacific Ocean. Rocky Mountains Park, Yoho, Glacier and Revelstroke Parks are situated on the main line of the Canadian Pacific Railway; Jasper Park and Mt. Robson reserve are along the Grand Trunk Pacific Railway; Waterton Lakes Park lies south of the Crows Nest line; and Strathcona Park is situated toward the center of Vancouver Island.

Three of these parks are in Alberta, the remaining five are in British Columbia.

Rocky Mountains, Yoho, Jasper, Mt. Robson and Waterton Lakes Park lie within the Rocky Mountain system of the Cordillera; whereas Glacier Park is in the Selkirks and Revelstroke Park is along the edges of the Selkirk and Columbia ranges.

From a scenic point of view these parks are all different and yet all attractive in various respects. Each of these pleasure grounds will be briefly mentioned.

THE ROCKY MOUNTAINS PARK.[1]

The Rocky Mountains Park of Canada is the largest and oldest of the Dominion national playgrounds. By an Act of Parliament in 1887 an area comprising 260 square miles was "reserved and set apart as a public park and pleasure ground for the benefit, advantage and enjoyment of the people of Canada." In 1902 this reservation was enlarged to include 4,900 square miles, but as this was found to be too large an area to preserve properly, the boundaries were reduced in 1911 to inclose 1,800 square miles, which is the present size of this world-known playground.

This reservation lies entirely on the east slope of the Rocky Mountain system in the Province of Alberta and extends from the western edge of the plains westward to the summit of the Rocky Mountains, which is also the continental watershed.

This park includes the entire drainage basin of the Bow River within the Rocky Mountains and has roughly the form of an isosceles triangle with the base running in a northeast and southwest direction. The gateway to the park from the plains is also a natural portal to the mountains and is known as the Gap.

This reservation is commonly known as "Banff Park" since it includes the town of Banff, one of the best known and most popular mountain tourist resorts in North America.

Banff and Lake Louise, both well known resorts in the Canadian Rockies, are the only two distributing centers for tourists within this park.

The Rocky Mountains Park contains many features that would attract the general public, the nature lover, the artist or the scientist. It embraces the most rugged, picturesque and majestic part of the Canadian Rockies; many lakes with superb, artistic setting, the sulphur-hotsprings at Banff, and above all a museum of scenic beauty so extensive and so varied that it equals any in the world. The contrast of forested lower slopes, rock-barren, towering escarpments and pinnacles, capped with snow and ice, and lakes large and small nestling in a forest or in a rock face, offer variety and enchantment to the visitor. The topography of the park is rugged and distinctly Alpine in character. The lowest valleys reach down to 4,200 feet above sea-level, while the highest peak is 11,870 feet, seen in the Matterhorn of the Canadian Rockies—Mt. Assiniboine.

Physiographically there are three very distinct structural features to be observed within this park. The first of these is the sharp line of demarkation between the low rounded ridge of the inner foothills and the gray massive limestone mountains, void of vegetation and lightened by patches of snow manteling the upper slopes of the massifs. This break between these two physically different units is marked by an almost perpendicular escarpment, 2,500 to 3,000 feet high. So sharp is this break that it is possible to walk along the extreme eastern base of the Rocky Mountains. This feature is particularly noticeable between latitudes 49 and 52 degrees. This escarpment marks the front of an overthrust block which when the mountains were uplifted was thrust in places several miles over the plains to the east. At the base of the escarpment is exposed the overthrust fault which farther south is called the "Lewis Thrust." Within the eastern edge of the park along this fault the Cambrian beds are thrust over the lower Cretaceous formations.

The other two structural features of note within the park are to be found in the mountains themselves; two thirds of the eastern slope of the Rocky Mountains consist of a series of sharply defined ridges all parallel to one another which present a steep escarpment on their eastern face and a more gentle slope toward the west. These ridges are huge uptilted fault blocks of rock, the more westerly blocks having been thrust partly over the block in front of it. The rocks in these fault blocks range essentially from Devonian to Cretaceous in age. The mountains in the western one third of the park are much older and belong to the pre-Cambrian and Cambrian periods. These formations have been up-arched into a broad fold which defines the backbone of the Rocky Mountains system, as well as the continental watershed. The rocks in this portion are for the most part lying nearly horizontal. There is a sharp break which is represented by a fault between the younger formations on the east and the older formations on the west. The rocks within this park are entirely of sedimentary origin.

A perfect reflection of Mount Assiniboine seen in Lake Magog. Note the wierd face-like form of some ferocious animal when viewed from the side.

Banff and Lake Louise (Laggan) although only 34 miles apart are very different as to location and scenery. The former is situated in the second range of the Rocky Mountains, on the floor of the Bow Valley at an elevation of 4,542 feet above sea-level. Banff is the headquarters of the park with inclosures containing all varieties of mountain animals including several buffalo. It also contains a museum, meteorological station, headquarters of the Royal North West Mounted Police and the only food distributing center for the entire park.

Lake Louise is situated at an altitude of 5,670 feet above sea-level and 533 feet above the railway at Laggan. The scenic features are truly Alpine, consisting of a valley closed at one end by a glacier, surrounded by rugged mountains of flat-lying quartzites, limestones and shales, whose summits average over 10,500 feet, and fringed with perpendicular cliffs or more gracefully curved slopes heavily timbered. The floor of the valley contains a lake of matchless beauty and the outlet of the valley hangs 600 feet above the floor of the Bow valley.

The highest and most prominent mountains are found on or close to the continental divide. The most lofty peaks include Mt. Assiniboine (11,870 feet); Mt. Temple (11,626); Mt. Hungabee (11,447); Mt. Victoria (11,355); Mt. Deltaform (11,225); Mt. Lefroy (11,220); Mt. Ball (10,825); Mt. Balfour (10,731); Mt. Fay (10,612); Mt. Aberdeen (10,340); Storm Mountain (10,309).

Among the many lakes of special individual scenic beauty that attract the tourist are Louise, Minnewanka, Vermilion, Bow, Hector, Spray, Shadow and Moraine Lake in the valley of the Tean Peaks.

Within the limits of the park there are 300 miles of trails which are frequently traveled, and over 125 miles of carriage road. The government has taken steps to encourage trail travel by the erection of cabins at various points along certain trails. A telephone system is also being installed.

A motor road is being constructed from the plains to the coast. It is already completed through this park and crosses the continental divide at Vermillion Pass, fifteen miles west of Banff.

YOHO PARK.

Yoho Park, containing about 560 square miles, is situated on the western slope of the Rocky Mountains adjacent to the Rocky Mountains Park. The Kicking Horse River, rising on the continental watershed at the pass of the same name (locally called the Great Divide), divides the park almost through the center. The grade of the upper part of the river is very steep; at one point

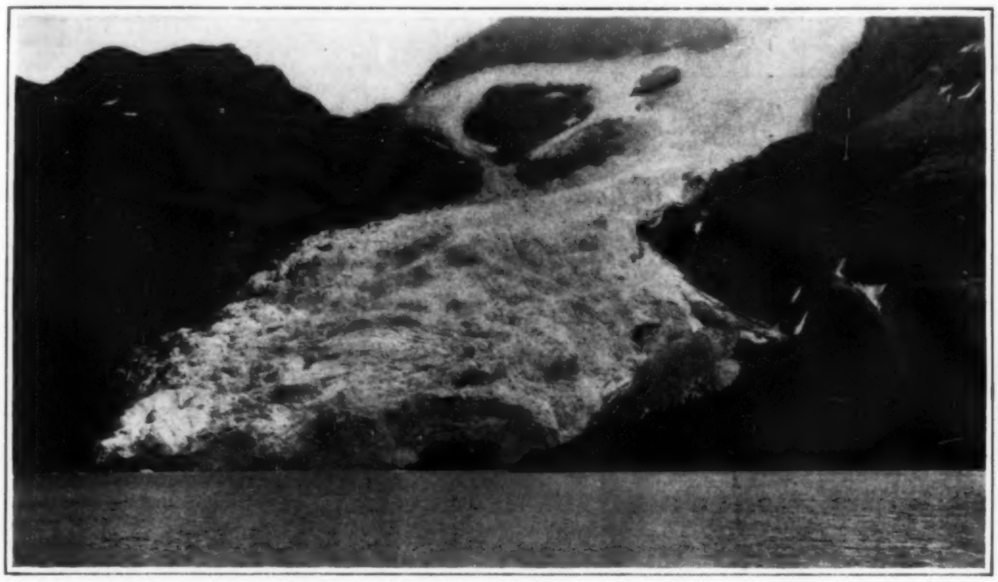
*Courtesy of *Science Conspectus*.

[1] Published by permission of the Geological Survey, Ottawa.

near the pass, in a distance of 2½ miles there is a difference in elevation of 900 feet.

Yoho Valley, the largest tributary from the north, shows distinct evidence of the handiwork of the glaciers. Takakkaw Falls, nearly 1,200 feet high, and Twin Falls, about 500 feet high, entering the Yoho from either side, rank among the most superb in the continent. Both are formed in massive middle Cambrian limestones and both come from typical hanging valleys inclosing glaciers. The Yoho glacier closes the northern end of the valley. The many peaks in the President range on the west and the Wapituk range on the east, present a panorama truly majestic.

Mention can only be made of such places of particular scenic interest to the tourist as the Ice River Valley surrounded by such peaks as Mts. Goodsir (11,676), Vaux (10,881), and Chancellor (10,751); Ottertail Valley; McArthur Pass and the Cataract Valley with Lake McArthur, Lake O'Hara, Mt. Odaray (10,165), Cathedral Mountain (10,454), Mt. Biddle (10,876), Mts. Hungabee (11,447); Huber (11,041); Mt. Victoria



Berg Lake and Robson Glacier, in Mount Robson Park. Continuous movement in this glacier, especially in summer, is evidenced by the creaking and groaning sounds which it makes.

(11,355), and many other peaks over 10,000 feet in the Bow range which forms the continental watershed. All of these mountains are readily accessible and can be climbed by the aspiring mountaineer. Mt. Stephen (10,485) one of the best known, can be easily climbed, and from its summit a magnificent panorama can be viewed. On the north slope of Mt. Stephen there is a small lead-zinc mine located 1,000 feet almost vertically above the railway.

Geologically this park is especially unique. Along the railway there is exposed one of the thickest Cambrian sections in the world. The total thickness of a continuous conformable series of quartzites, limestones and shales from the base to the top of the Cambrian was found to be over 18,500 feet.[1]

The rocks in the park are all sedimentary with the exception of a small area of igneous (plutonic) rock exposed in the Ice River Valley. These rocks are alkaline in composition, ranging from nephelite and sodalite syenites, through ijolites and urtites to jacupirangites and other basic affinities. These rocks have been fully described by the writer in the memoir mentioned above. The mineral sodalite has a beautiful blue color and is much in demand by tourists as souvenirs.

GLACIER PARK.

Glacier Park comprises an area of 468 square miles and is situated at the summit of the Selkirk range. This reservation is the most westerly of the three situated on the main line of the Canadian Pacific Railway. Rogers Pass, the summit of the Selkirks, is located about the center of the park.

The scenery in Glacier Park is equally grand as that of the Yoho or the Rocky Mountains Park, but it is nevertheless quite distinct. The mountain peaks are more numerous and more pointed in form than those in the Rocky Mountain system. This difference of form can be accounted for geologically. The rocks are essentially pre-Cambrian in age and consist of schists, slates, gneisses and other metamorphic types badly contorted and broken. This portion of the Selkirks represents the old terrain from which much of the sediment was derived which gave rise to the great thickness of Cambrian and other Paleozoic formations in the Rocky Mountains.

Two physical features are of special note, and should

[1] Allan, J. A., Geology of the Field Map Area—*Memoir 55* Geological Survey of Canada, 1914.

be visited by all tourists; the Illecillewaet and Asulkan glaciers, and the Nakimu caves. Both are reached by good trails. Within a few minutes' walk from the railway it is possible to stand on the frontal lobe of a real living and moving glacier. This gives one an opportunity to study glacial phenomena in the process of change.

The Nakimu caves (caves of Cheops) are situated in a cirque-like basin toward the head of Cougar Creek on the west side of the Illecillewaet Valley. These caves are wonderful in their formation. They consist of a series of irregular subterranean channels which have been formed by running water from a crystalline limestone. There have been several miles of these tunnels explored and they furnish an interesting and somewhat eerie expedition to the visitor. A considerable portion of the park still awaits the explorer and adventurer.

Game is abundant, especially the grizzly and black bear, whereas the more open mountain slopes offer a museum of floral variety for the botanist.

JASPER PARK.

Jasper Park, although still quite young, is year by year becoming better known. This reservation is situated on the Athabaska River west of Edmonton and comprises an area of 1,000 square miles, which includes a strip 20 miles on each side of the railway and extending from the foothills west to the continental watershed on either side of Yellowhead Pass which also marks the western boundary of Alberta.

The position of Jasper Park in relation to the Rocky Mountains is quite similar to that of the Rocky Mountains Park 200 miles to the south, in that they both occupy the entire eastern slope of the mountain system from the plains to the continental divide.

The topography in Jasper Park, although by no means so rugged and precipitous as that in higher altitudes to the south, is nevertheless attractive, pleasing and varied in its character. The valley of the Athabaska is broadly rounded and well forested. The broadened river course forming Jasper and Brule Lakes and the meandering braided character of the stream in places add beauty to the landscape when backed up by a forested slope terminating in a massive gray limestone escarpment, with well-nigh perpendicular walls. Roche Miette is a good example of this.

The topography of the ranges west of Jasper is quite distinct from that to the east. A line crossing the railway about two miles east of Jasper and drawn in a northwest-southeast direction divides the younger portion of the Rocky Mountains consisting largely of westerly tilted monoclinal fault blocks of Devonian to Cretaceous rocks, from the older portion represented by Cambrian and older rocks that make up the ranges which mark the continental watershed. This structural feature is similar to that more fully described under the Rocky Mountains Park.

A physical feature that is making the park well known is the presence of sulphurous hot springs (Miette hot springs) situated toward the eastern end of the park about seven miles from the railway in the valley of Fiddle Creek. There are several of these springs and the temperature varies to a maximum of 127 deg. Fahr. The water in some of these springs has been proved to have certain medicinal properties for rheumatics.

MOUNT ROBSON RESERVE.

Mt. Robson Park reservation is under the control of the Province of British Columbia; it therefore is not a Dominion park.

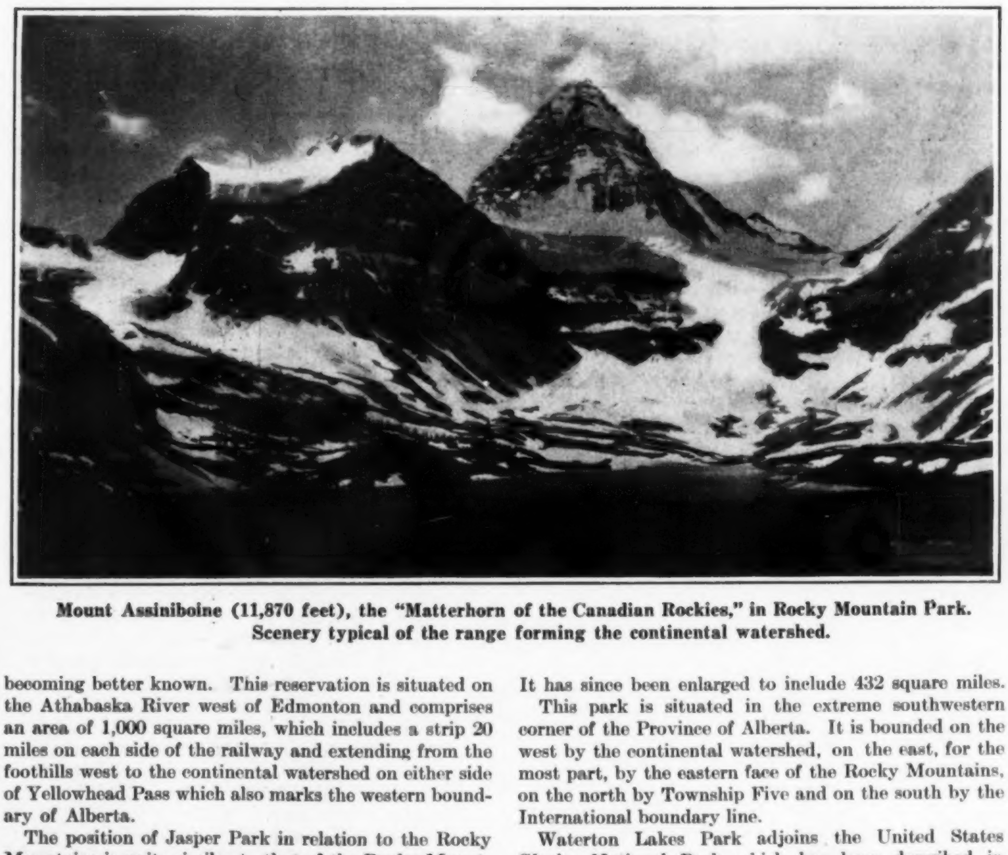
This reservation joins Jasper Park on the west and includes the ranges to the northwest of Yellowhead Pass, forming the continental watershed. This park is still comparatively young and has not yet been thoroughly explored. It however, contains some of the most majestic and rugged scenery in the continent. Mt. Robson, "the Monarch of the Canadian Rockies," has an altitude of about 13,700 feet above sea-level. It is the most lofty peak in the Canadian Cordillera south of the Yukon. There are a number of other peaks in the Robson group equally as magnificent, but much lower in elevation. Associated with these summits are many square miles of glaciers and snowfields that add beauty to the panorama.

Berg Lake and Lake Kinney are two beautiful large sheets of water at the base of Mt. Robson; they are connected by the Valley of a Thousand Falls.

The rocks in this district are chiefly pre-Cambrian and Cambrian in age and are all of sedimentary origin.

WATERTON LAKES PARK.

Previous to 1914, this was the smallest Dominion mountain reservation, having an area of 16 square miles.



Mount Assiniboine (11,870 feet), the "Matterhorn of the Canadian Rockies," in Rocky Mountain Park. Scenery typical of the range forming the continental watershed.

It has since been enlarged to include 432 square miles.

This park is situated in the extreme southwestern corner of the Province of Alberta. It is bounded on the west by the continental watershed, on the east, for the most part, by the eastern face of the Rocky Mountains, on the north by Township Five and on the south by the International boundary line.

Waterton Lakes Park adjoins the United States Glacier National Park which has been described in *Bulletin* No. 600 of the United States Geological Survey.

Although this reservation has not yet become well known on account of the lack of roads and trails, yet it is bound to become a popular resort especially for the citizens in Southern Alberta. One of the principal features at present in the park is the chain of lakes after which the park has been named. The upper Waterton

Lake extends for about three miles south of the International boundary.

This chain of lakes is walled in by steep promontories and rock escarpments which rise to an elevation of 8,000 feet. The lower lake lies just outside of the mountains and is separated from the middle and upper lake by a broad delta of alluvial material carried down by Blakiston Creek (Pass Creek). The lakes within the mountains are entirely of glacial origin. There are other equally picturesque lakes within the park; of these Summit Lake (Oil Lake) lies in a large cirque close to the continental divide and extends across the boundary line into the United States. This lake is drained by Oil Creek, so called because small quantities of crude petroleum have been obtained in three or four drill holes in this valley.

The scenery within the park is typical of the eastern part of the Rocky Mountains.

There are no true glaciers, but large patches of perennial snow may be seen on many of the higher slopes. Very little is yet known of the northern half of the park.

REVELSTROKE PARK.

Revelstroke Park is the youngest and smallest of the Canadian Cordilleran playgrounds. It was set aside in June 1914 and consists of 48 square miles in the vicinity of the town of Revelstroke on the main line of the Canadian Pacific Railway. It is located on the extreme western flank of the Selkirk range on the eastern side of the Columbia River.

The park is being opened up rapidly by the construction of trails and a motor road to the top of Mt. Revelstroke. This peak is only 6,500 feet high, yet from its summit there is a magnificent panorama towards the Selkirks, the Gold ranges, the Cariboo district and up the Columbia valley. An endeavor is being made to make this park a popular winter resort.

STRATHCONA PARK.

In June, 1910, the government set aside an area comprising approximately 260 square miles to be used as a reservation and playground in the center of Vancouver Island. This area was called Strathcona Park. Since the original limits of the park did not include much of the finest lake and mountain scenery, the government in 1913 extended the limits of this reservation to include about 800 square miles.

Strathcona Park is situated about the center of Vancouver Island; the northern gateway is about 120 miles north of Victoria, 75 miles west of Nanaimo and 20 miles north of Alberni.

Although little is yet known of much of the park, each season is bringing it before the public, and showing that this reservation is worthy of being ranked as equally wonderful in the works of nature as other parks referred to above, which are situated far inland and in lofty mountain ranges.

Buttles Lake affords a picturesque watercourse 25 miles long and 1 to 2 miles wide, winding down the center of the park. Streams often with waterfalls enter on either side through heavily timbered shores which terminate in rugged rocky slopes often snow-clad and cold.

Campbell Lake consists of two basins, the lower being 7 miles long and 1½ miles wide, while the upper one is about 6 miles long.

Numerous small lakes which, like the larger ones, are of glacial origin, add charm to the surroundings.

The topography on the whole is rugged since the altitude ranges from sea-level to nearly 7,500 feet. Elkhorn Peak, about 7,200 feet, is known as the Matterhorn of Strathcona Park.

The flora of the park has been studied by James M. Macoun of the Geological Survey of Canada. He reports having noted at least 350 species of phenogamous plants in the park which are very representative of the whole flora of British Columbia.

Potassium Photo-Electric Cells—II*

A Study of the Relationship of Illumination and Current

By Herbert E. Ives

[Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2082, Page 350, November 27, 1915]

COMPARATIVE RESULTS OF SEVERAL CELLS.

With the apparatus as described under section 4, a large number of miscellaneous illumination-current curves were taken for all the cells above described. These were made with different applied voltages. At first the aim was to use one voltage throughout, and one was selected which would not cause a dark discharge in any of the cells. Afterward it became evident that the phenomenon under study was a function of voltage, so some extra curves were made at different voltages.

At various times during the experiments on high resistances, curves similar to Fig. 3 were obtained from cell *a*. As long, however, as polarization and other troubles were not entirely eliminated these results could not be accepted as conclusive.

Had no other cell been at hand, the conclusion could well have been drawn that this is the true relationship between photo-electric current and illumination. The opportunity afforded by the possession of several cells, however, made it possible to demonstrate that the phenomenon is much more complicated. Each of the several cells shows a different illumination-current relationship. Curves both concave and convex, of most extreme type, as well as some with double curvature, appear. It appears, too, that the relationship is, to a varying degree, in different cells, a function of the applied voltage.

In no case is this relationship linear. If only a comparatively short range of illumination be used, few points taken, and a certain voltage range not overstepped, curves may be obtained which appear to be straight lines. When compared with other curves of the same family, that is, obtained with higher and lower voltages, the points which deviate by amounts apparently within the errors of measurement are actually found to be true indications of curvature. Furthermore, with the cells *j* and *k*, in which the nearest apparent approach to linearity was found on first measurement, the observations were repeated many times, running up and down the curves, proving the curvatures to be real and of significance. The four curves of cell *j* are obviously developments of each other. Cells such as *j* and *k* might easily be hastily assumed to show the heretofore believed linear relationship. Only the refinement of measurement called for by the requirements of photometric application would make clear with these particular cells that this is not so. Fortunately, the extreme differences among all the cells leave no doubt of the exceptional and accidental character of the linear relationship when found.

SUGGESTED REASONS FOR THESE RESULTS.

A study of the illumination-current relationship shows that in any one cell the relationship is a function of the applied voltage, although to a varying degree in different cells. Thus, the variation in character of curve in cell *c*, in going from 2 to 348 volts, is much greater than in cell *k*. It is evident that different voltages correspond in different cells to different characteristic curves. Thus cells *b*, *f*, and *c* show the same type of curves at voltages 348, 261, and about 100. Nor does it appear possible in any one cell to obtain all types of curves by mere voltage change. For instance, the two extremes exhibited in cell *a* (concave upward) and cell *e* (concave downward) are not attained in cell *c* at the extreme voltages used, other phenomena entering to interfere at the high voltage and lack of sensibility preventing a study of lower voltage effects.

Differences of pressure, of gas, of electrode distance, of surface, exist among the cells, and it is to these that we must look for explanation of the phenomena. These differences have been recorded in the description of the cells. Additional evidence as to the different electrical conditions holding in the cells is afforded by the voltage-current curves (made subsequently to the illumination-current curves) for a chosen medium illumination. These show differences, ascribable to different pressures and electrode distances, which are as extreme as those between the illumination-curves, which they resemble in some ways.

A study of previous work on the photo-electric effect[17] shows that curves possessing nearly all the characteristics of the cells experimented with, have been obtained where the variables were voltage, electrode distance, and pressure, illumination being maintained constant. J. J. Thompson[18] develops two equations, the first dealing with the conditions well below the voltage, pressure, and electrode distance at which discharge occurs in the dark, and the second with the conditions near the point of discharge. From the first of these equations it follows that for low voltages the current should obey Ohm's law, for higher voltage saturation would set in. From the second of these equations it follows that the current should increase, owing to ionization by collision, according to a power of *e* determined by electrode distance, etc.

As the most conclusive summary of these results it may be said that the reasoning and equations just quoted are applicable to the present case if variation of illumination and variation of voltage are considered as similar in influence. But certain peculiarities of these illumination-curves are not to be overlooked. The voltage-current curves of cell *c* show at the lowest illumination apparent complete saturation; at slightly higher illuminations approach to saturation and subsequent increase ascribed to ionization by collision. But at higher illuminations the increased current again approaches saturation, making a saturation-curve with a depression. At still higher illumination this depression disappears and a simple characteristic curve is obtained, apparently approaching saturation uniformly. These data are of interest in connection with the characteristic curves for the inert gases, recently published by Franck and Hertz,[19] which show a series of steps.

The most striking feature of the illumination-current curve of cell *c* is the series of steps shown at higher voltages. These steps, caused by varying illumination, are similar to the voltage-current curve steps just referred to, and are additional evidence that illumination variation must, in these cells, be considered as of similar effect to voltage variation. The data of cell *j* (argon-filled) indicate similar stepped curves, due to illumination variation.

The next step in the study appeared to be the intentional variation of electrode distance and pressure, the factors not variable in the completed cell.

Cell with variable electrode distance.—The easiest factor to vary and, as it was thought (noting the results of Stoletow), the most likely to show in the results, was electrode distance. A special cell was, therefore, constructed, shown in Fig. 6 (*g*). The platinum electrode was attached to an iron rod which slid in a glass tube, and was connected by a fine coil of copper wire to a platinum wire sealed in the glass and going to the batteries. The cell was first filled in a horizontal position and sealed off at the best vacuum obtainable with the Gaede mercury lamp, the iron rod was then held in position by a selenoid, the cell turned to the upright position, and the potassium melted and flowed into its final place. The electrode was afterward easily put in any desired position by inclining and tapping the tube.

Two curves obtained with the cell, for electrode distance of 2 and 40 millimeters, are both concave to the illumination axis, and while the short-distance curve is somewhat less concave than the other, it is evident that variation of electrode distance alone, at this pressure, does not produce rapid changes in curve type.

Cell with variable pressure.—A cell similar to *g* was next constructed, differing in the possession of a side tube containing a ground stopcock and a ground cone, fitting the ground sleeves of the pump system *h*. This cell was made a little differently from the last, being filled in an upright position through a lateral constricted tube, the solenoid being in position throughout. Of course the proper procedure would be to have the cell constantly connected to pump and gage, but this was not possible to arrange in the present case. Trouble was expected from the stopcock, and leakage did, in fact, spoil the potassium surface after two days. In that time, however, it was possible to allow the surface to reach a steady state after its first rapid drop in sensitiveness and to run several curves at several pressures of hydrogen. The change in pressure was made by replacing the cell on the pump, securing a good vacuum, and introducing gas from palladium foil. Measurements were made as soon after as practicable. Resulting curves were made at the three pressures 0.01, 0.06, and 0.6 millimeters, and, while by no means offering a complete picture of the variation of the illumination-current relation, show clearly that it is a function of pressure, voltage, and electrode distance. From the results of Varley it is to be expected also that the nature of the gas filling the tube will affect the relationship.

Two generalizations appear to be justified from study of these curves:

A. There is a qualitative agreement throughout between the effects of (1) increase of electrode distance; (2) increase of pressure; (3) decrease of voltage.

B. The course of the changes from the most intense

* From the *Astro Physical Journal*.

[17] See J. J. Thompson, *Conduction of Electricity through Gases.*

[18] *Ibid.*

[19] *Berichte der Deutsch. Phys. Gesel.*, 20, 929, 1913.

conditions (high voltage, low pressure, small electrode distance) to the least intense (low voltage, high pressure, large electrode distance) appears to consist of at least three and perhaps more stages.

First stage.—At most intense conditions a current which approaches saturation with increase of illumination (curves concave toward illumination axis).

Second stage.—A current increasing with illumination in the same manner that a constant illumination current increases as the dark discharge voltage is approached (ionization by collision).

Third stage.—This second current approaches saturation.

A fourth stage is suggested in the curves of cell *c*, where, at a relative illumination 0.8 for the higher voltages, a new upward turn is taken, followed again by apparent slow approach to saturation. In fact, it appears probable that the illumination-current relationship may be plotted as a curve whose ordinates increase in value in steps.

The most general statement of the effects produced by light is that already made, that variations of illumination appear to act in a similar manner to variations in voltage, producing currents obeying Ohm's law over short ranges, currents which approach saturation, which increase in value as though through ionization by collision, etc. The quantity of electrons liberated is apparently as potent a factor as is voltage in altering the character of the discharge.

Other differences between the originally studied cells may have been of effect. For instance, the somewhat different character of surface with consequent different amounts of normal and selective effect. It would be of interest in a more complete and detailed study of this relation to examine the normal and selective effects separately in sodium potassium alloy.

A point of extreme importance, which must here be emphasized, is that these results apply of necessity only to gas-filled cells. The best vacuum attained in the cells here described was not sufficient to produce saturation. Traces of gas, and probably mercury vapor, were always present. What will happen in a cell exhausted by the new Gaede molecular pump with the assistance of liquid air, is a question still open for investigation. It must be remembered, however, that all previous work on this relationship has been done with no better vacua than here used; that the most widely exploited cells, those of Elster and Geitel, are purposely filled with a gaseous atmosphere. In short, this work stands in contradiction to all researches which have hitherto been considered proof of the linear illumination-current relationship.

Looked at from the standpoint of photometric application, these results are the opposite of encouraging. The most that can be said is that by careful choice of electrode distance, gas, pressure, and voltage, cells may be produced which, for a more or less limited range, show a linear relationship between illumination and current.

Every cell would, therefore, have to be either tested for this relation while still on the pump, or have its calibration-curve determined under conditions to be rigidly adhered to afterward. Any change in pressure, or possibly (a point not touched on here) any aging of the surface would necessitate a checking of this calibration.

A further question: should colored-light photometry be attempted with cells made with the characteristic thus determined, would there be uniformity between different cells and the permanence in any one cell of the distribution of sensibility through the spectrum. Data on wave-length sensibility obtained during the course of this investigation indicate possibilities of wide differences from cell to cell, but this question is left for further study.

It must not be forgotten, however, that the photo-electric cell possesses enormous sensitiveness and that the conclusions above reached do not affect at all its use as a detector, or for measurement by substitution methods where the lights under comparison are of identical quality. A set of electric lamps of the same type could, for instance, be brought to the same candle-power by so regulating their voltage that they gave the same photo-electric current in the cells, or relative candle-powers could be determined by finding the distance at which different lamps gave the same deflection. A degree of sensitiveness greatly exceeding the eye should be attainable for such work. There is not the need, for this kind of photometric adjunct that exists for an "average eye" for standardization of color measurements.

SUMMARY AND CONCLUSIONS.

1. Photo-electric cells and auxiliary apparatus have been developed by which the character of the photo-electric current may be studied without disturbance by spurious effects.

2. The use of the quadrant electrometer for measuring photo-electric current has been studied and the conditions determined such that its characteristics introduce no distortions in the results.

3. The illumination-current relationship has been found not to be linear, but to be a complicated function of voltage, electrode distance, and pressure, similar to the voltage-current relationship.

4. It is concluded that gas-filled photo-electric cells do not possess the qualities most desirable in a physical photometer.

The writer takes pleasure in acknowledging the assistance and co-operation of Mr. E. Karrer during a portion of this work.

German Army Administration*

A Lesson in Prepardness

With a reluctant admiration our enemies speak of the organized ability and capacity of our Army administration. As the grey flood of a "Nation in Arms" flowed over Belgium and the north of France, terror crippled our western adversary and his contemplated offensive. Each little drop of German manhood had found its assigned place in rivulets, streams and currents, that fed the flood with extraordinary swiftness. Russia's mobilization of many months as well as the precipitate one of France was overtaken by the prudent, faithful and gifted peace work of our War Ministry.

But the supply of the marching and ever shifting millions between east and west by railroads must certainly exceed human possibilities. For our enemies saw and felt it in their own cases! Hostile leaders in the east and west are still complaining of a scarcity of artillery ammunition. We also saw our accumulated supply of projectiles rapidly disappearing after the commencement of the war. But again the enemy's astonishment changed to terror as it became apparent that the organization of German military administration, in spite of its rigidity, was also adaptable, and that without appreciable exertion was soon able to provide abundance when scarcity had threatened. Our army was more than supplied by two officials who work in the Ministry during war the same as in peace. A colonel and a lieutenant colonel as chief of the field and foot artillery sections perform with their left hands, so to speak, the work which an English Minister attempts with an army of officials and volunteer helpers through calling of public gatherings and speeches to citizens and workmen. Probably both of the staff officers in question give more thought to the guidance of their branches of the service than to ammunition. Both are continuously engaged in creating new formations. One supplies the material needed for besieging hostile fortresses and for the armament of conquered places. In addition to the time required for these important things he must find leisure as artist, historian and master of arms, to decorate the Berlin trophy hall with trophies. The other officer, in addition to supplying his own branch of the service with equipment, has also to provide equipment to the infantry for field service, to the train for practice and transportation for the field post.

In such a manner works our War Ministry, the forge of the sword, which the supreme commander-in-chief can place in the hands of his chief of the general staff on the day of mobilization. But the working capacity of the forge is a factor in winning victories with which the bearer of the sword must constantly reckon. For this reason the War Minister accompanies the Imperial Commander-in-Chief at Great Headquarters. Here he helps in planning and undertaking. The plans of the field leader will always look to great and remote objectives. It may become the duty of the head of the Administrative Department to place limits upon the ambitions of the field leader whenever technics or human power cannot keep pace with the flight of imagination. Living in the midst of the great problems of the war he must be freed from the burden and cares of routine duty, and the heavy burden of work at home must be shouldered by an acting Minister of War. The War Minister at the front knows constantly what he can offer the field leader in the way of men and supplies. The Acting Minister, Excellence v. Wandel, appears before the Reichstag and is permitted to assume responsibility before Parliament because he, in order to save time, has often also to decide most weighty questions independently. In common with the War Ministers of Bavaria, Saxony and Wurtemburg, all working with equal will and spirit, he assembles all the forces of the empire for the field leader. The railroad tracks of the homeland, and the Ettape lines in the sphere of operations, are arteries, through which new lifeblood, in the shape of food, ammunition and other necessities flows to the fighting fronts from the heart muscle of the Army, the War Ministry. In spite of all this its effectiveness awakens no enthusiasm. Poetry and legend seem to prefer the red house (General Staff Office) in the Konigsplatz to the yellow-brown (War Ministry) not far from the Potsdam Gate. There the Prussian clerk rules at his high altar midst dusty archives.

We fight not on a single front. We show head and breast to a world from which we are entirely cut off. From home sources alone can the War Ministry create the lifeblood needed for feeding the fighting fronts. The collection of the available supply of raw material for the production of new equipment would alone demand a special minister in other countries. This work is carried out by a major charged with looking after the business of the chief of section. We entertain an army of prisoners of war much larger than any peace army. This is provided for and usefully employed, not through any new authorities, but merely as a side issue of the housing department, active alike in peace and war. The rapidity with which the new German armies are created recalls to the foreign newspapers the wonders of the "Thousand and One Nights." A group of five officers of the War Ministry controls this work which arouses even German astonishment. Other groups, little larger or smaller, care for weapons, equipments, food, clothing, wagons and horses, for sick and wounded or for survivors, supervise the work of factories, guide presents to the front and find the way for the field post. He who thinks that it requires an army so to collect, harness up and organize the powers of seventy million Germans and of their domestic establishments little knows the capabilities of our army.

In time of peace it prepared the contested successes with a personnel of 759 men, 111 officers, 47 higher and 37 medium officials; 83 chancery clerks and 107 lower officials. Under the roof of a large Berlin newspaper building 150 beings alone conduct the issue of books. The entire personnel, exclusive of workmen, far exceeds that of the War Ministry. The work that in war is Germany's pride and her enemy's envy is carried by 2,750 men. The organization which they envy us was created not only by intelligence and genius. It rests upon the traditions of 200 years, on royal authority and on the faithfulness in little things, which the royal corporal taught to us Prussians with the crutch-stick, which the "most faithful of the faithful," old Roon, practiced as a pattern, in that house where "self" and "I" had no place, and where pride and service was joined to self-sacrifice.

*Extracts from an article on German Army Administration by Otto v. Gottberg, which appeared in the *Tagliche Rundschau*, of August 13, 1915. Republished from the *Army and Navy Journal*.

Eye Injuries from Alkalies

The daily papers and magazines of the past two years, at home and abroad, have contained numerous instances of more or less serious injuries to the eyes from the explosion of the central rubber bags of some sorts of golf balls, filled with strong solutions of alkalies. Attention being in this way drawn to the dangers from alkalies in golf balls, it is well worth recalling the possibility of injuries of the eyes from other forms of alkalies.

A boy was busy whitewashing his father's fence when another boy came along and they began to talk together as boys will talk; from talk it was not far to guying and sport, then came pulling and hauling. In the final struggle for the control of the brush, the friendly boy flapped the brush into the working boy's face, in so abundant a fashion that the lime in the whitewash entered one of the eyes and injured it for life, leaving a scar which neither medicine nor treatment can get rid of.

Another injury recently reported is one not so likely to happen to any boy. A boy was so anxious to have his face clean and presentable at dinner that he made up a thick lather and then so completely enveloped his neck, head and face with it that some entered the eyes, burning the eyeballs so that the boy was hardly able to see at all. This boy is injured for life, owing to his own thoughtlessness. If he or his parents had attended any public health lectures on the care of the eyes, they would have understood the risks of using strong alkalies near the eyes in any fashion.—*Journal of the American Medical Association.*

Designing Small Dynamos and Motors

Instructions in the Theory and in Details of Winding

By Chas. F. Fraasa, Jr.

WHILE answering an inquiry for data as to how to rewind a small motor for use as a generator, it occurred to the writer that probably the data and calculations involved would be of interest to the readers of this periodical.

In the following article these calculations have been simplified and explained, and sufficient data is given to enable the reader to redesign small machines for use either as motors or generators.

The plan followed consists in determining the armature output and the armature and field losses, and then deducting the later from the former to obtain the available output. The final design is then worked out on the data obtained in this preliminary design.

Some very good bargains in old or burned-out machines may occasionally be obtained which when rewound will give satisfactory results. It should, however, be borne in mind that a machine having a laminated field magnet will not make a good generator, as it will not retain enough "residual magnetism" to enable it to start generating.

Cast iron, cast steel, or wrought iron, however, retain magnetism after the machine has stopped, and machines having field magnets of these materials may be rewound and used as generators.

lines of force S times in T seconds, the induced electromotive force in volts E is given by the formula:

$$E = \frac{\phi N S}{100{,}000{,}000\ T}$$

Practically all small motors and generators are bipolar. A bipolar armature has the conductors connected so that there are two paths through the winding; one half of the armature conductors are in series in each path, and the two paths are in parallel between the brushes. This will be explained in the design of the armature winding.

The voltage generated in an armature winding is proportional to the number of conductors connected in series, the flux per pole, the number of poles, and the number of revolutions of the armature per second. The formula for armature voltage then becomes,

$$E = \frac{\phi P N S}{100{,}000{,}000\ Z\ 60}$$

Where, E = induced volts,
ϕ = flux per pole,
N = number of conductors,
S = revolutions per minute,
Z = number of paths through the armature between brushes.

inches long axially. The measured pole arc is 2⅜ inches long, and each pole covers five armature teeth. The pole cores have a cross-section of 2 by 2¼ inches.

Armature.—Laminated, 2½ inches in diameter and 2¼ inches long, having fifteen 5/16-inch round slots. The commutator is 1¼ inch in diameter and has fifteen copper segments, having a face ¾ inch long.

The drawings, Fig. 2, dimensioning the field magnet, and Fig. 3 the armature disks were made from this data.

THE PRELIMINARY DESIGN.

Flux per Pole.—The area of the pole face is 2.375 by 2.25 = 5.34 square inches. The airgap density may vary from 20,000 lines of force per square inch in the smaller machines to 35,000 lines of force per square inch in machines of from ½ to one horse-power. Using a value of 25,000 lines of force per square inch in this design, the total flux per pole may be 25,000 by 5.34 = 133,500 lines of force.

Armature Ampere Conductors.—Working the preliminary design on a basis of one ampere per armature conductor and allowing 400 circular mills per ampere, we may next determine the number of ampere conductors which may be wound upon the armature.

Referring to the table of wire characteristics, Fig. 1, No. 24 d. c. c. magnet wire has an area of 404 circular

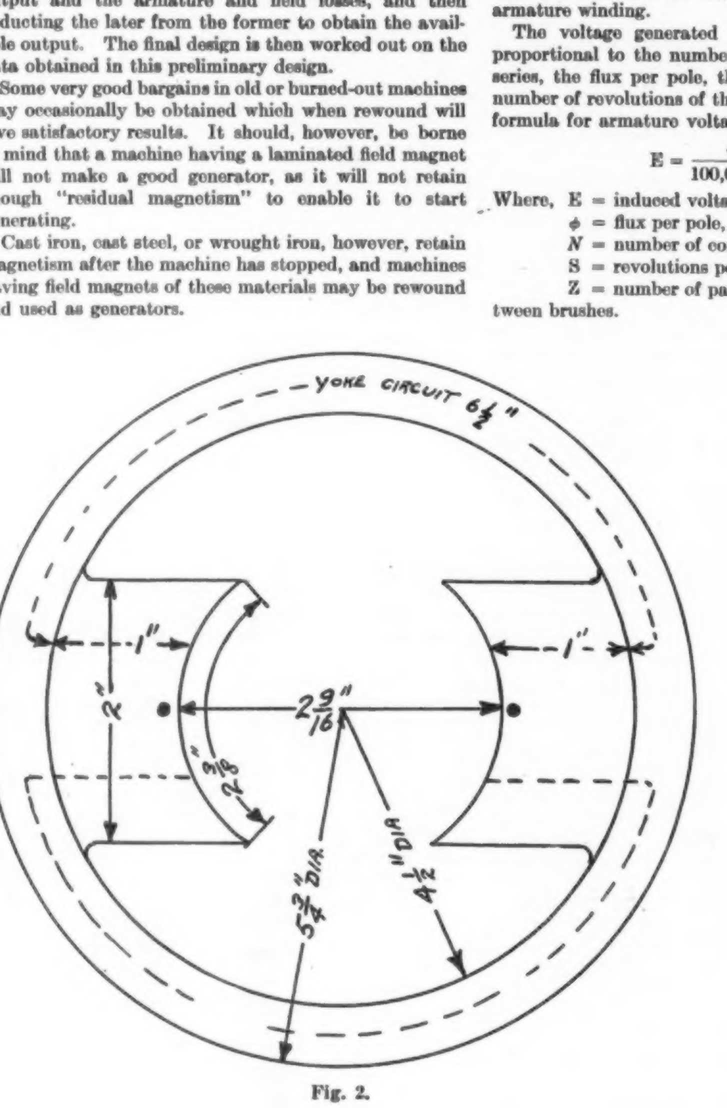


Fig. 2.

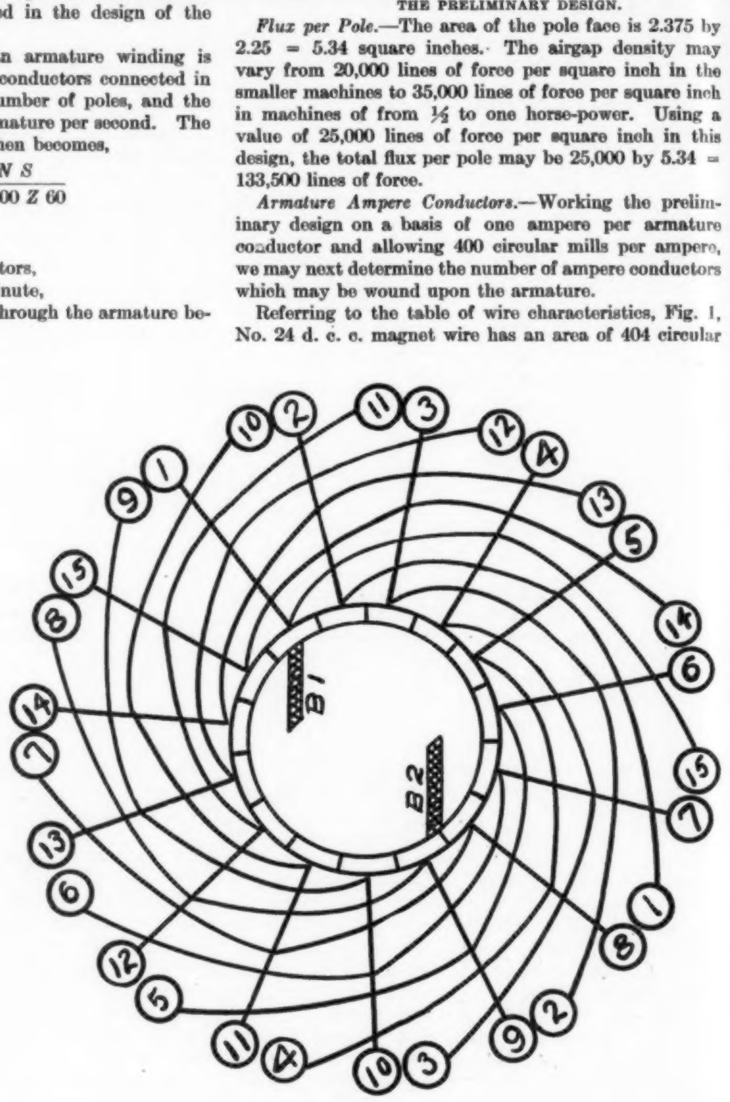


Fig. 5.

Judging from the inquiries received, the amateur usually makes the mistake of trying to get too much out of a given machine. With the present keen competition among manufacturers, they can be relied upon to have gotten the maximum rating available from a given frame. Of course, the machine may in some cases be operated at a higher speed, with a correspondingly increased output, but the amateur will find when rewinding, that with his limited experience and lack of facilities, it will be impossible to get as much wire in the armature slots as the manufacturer did, which materially lessens the output. For best results, it is well to be satisfied with a reasonable approximation of the original rating.

When a conductor moves across a magnetic field in a direction at right angles to the lines of force of the field, an electromotive force is induced in it. If the conductor forms a portion of a closed circuit, a current will flow in it. The magnitude of the induced electromotive force depends upon and is proportional to the rate at which the conductor cuts the lines of force, that is, the number of lines of force cut per second. If the conductor cuts across one hundred million (100,000,000) lines of force per second, an electromotive force of one volt is induced in it; if it cuts across one million lines of force one hundred times per second, one volt will also be induced in it.

If several conductors N connected to add their induced electromotive forces, cut across a magnetic field of ϕ

The product of the armature voltage and current gives the watt output of the armature. The current carrying capacity of the armature conductors is limited by the heating, and should not exceed a certain value determined by previous experience. The current carrying capacity of a conductor is usually stated in terms of circular mills per ampere. The circular mill is the area of a circle having a diameter of 0.001 inch. The current density in the armature copper of very small machines may be as high as 300 circular mills per ampere, while for machines of from ⅛ horse-power to one horse-power, this density may be from 400 to 500 circular mills per ampere. The current density in the field windings may be practically one half of these values, or 600, 800 and 1,000 circular mills per ampere. The accompanying table of wire characteristics, Fig. 1, gives the areas of magnet wires in circular mills.

ILLUSTRATION OF DESIGN.

Data.—The following data is from a small 110-volt, 1,750 r. p. m. motor of standard manufacture. It is of the bipolar type, having a cast-iron yoke ring with two inwardly projecting poles. The following are the principal dimensions:

Field Magnet.—Material, cast-iron. The external diameter of the yoke is 5¾ inches. The yoke is ⅝ inch thick, and 4¼ inches long axially. The armature tunnel bore is 2 9/16 inches in diameter, with pole faces 2¼

mills, and runs theoretically 1,260 wires per square inch of coil cross-section. In practice it will be found to run much less than this value, so we will assume a space factor of 60 per cent and thus allow for both the slot insulation and for the space lost in winding. The slots have a diameter of 5/16 inch, making the slot area 0.0767 square inch. The number of conductors per slot will then be 1,260 by 0.60 by 0.0767 = 57.98; let us say 56, and the total number of ampere conductors on the armature will be 840.

Armature Watt Output.—The armature may be operated at 2,400 r. p. m. Substituting the above values in the formula for armature voltage,

$$E = \frac{133{,}500 \times 2 \times 840 \times 2{,}400}{100{,}000{,}000 \times 60 \times 2} = 44.856$$

Since there are two paths through the armature in parallel between the brushes, and each has a capacity of one ampere, the current capacity of the armature is two amperes, making the watt capacity 2 by 44.856 = 89 watts.

Armature Losses.—Allowing for piling of the conductors where they cross on the armature ends, the average turn length will be 2 (2½ + 2½) = 10 inches. Since there are 840 conductors there will be 420 turns, making the length of wire on the armature $\frac{420 \times 10}{12}$ = 350 feet,

FIG. 1

		TURNS PER SQUARE INCH.		RESISTANCE AT 50° C.
B&S GAUGE	AREA IN CIRCULAR MILLS	SINGLE COTTON COVERED	DOUBLE COTTON COVERED	OHMS PER 1000 FEET.
13	5180	162	146	2.234
14	4110	200	182	2.817
15	3260	249	222	3.552
16	2580	316	285	4.479
17	2050	400	353	5.648
18	1620	492	432	7.122
19	1290	655	538	8.980
20	1020	767	625	11.32
21	810	942	745	14.28
22	642	1180	918	18.01
23	510	1400	1060	22.71
24	404	1710	1260	28.63
25	320	2070	1480	36.10
26	254	2520	1740	45.52
27	202	3010	2020	57.40
28	160	3620	2350	73.39
29	127	4260	2680	91.28
30	101	5090	3080	115.1
31	79.7	6000	3490	145.1
32	63.2	7050	3940	183.0
33	50.1	8100	4380	230.8
34	39.8	9400	4880	291.0
35	31.5	10.800	5400	366.9
36	25.0	13600	6930	462.7

Fig. 1.

Referring to the table of wire characteristics, No. 24 wire has a resistance of 28.63 ohms per 1,000 feet at 50 deg Cent. which will be somewhere near the operating temperature. Since the current flows through two paths which are in parallel between the brushes, the armature resistance will be one-fourth of the total resistance of the wire, or

$$\frac{350 \times 28.63}{1,000 \times 4} = 2.5 \text{ ohms.}$$

The armature loss in watts will then be the current squared, multiplied by the resistance, or 2 by 2 by 2.5 = 10 watts.

Field Winding Losses.—To determine the field losses, it will be necessary to design a winding for it on a basis of one ampere per turn. We will first have to estimate the flux densities in the various parts of the magnetic circuit.

Armature Core Density.—A flux of 133,500 lines of force pass through the armature from pole to pole. The

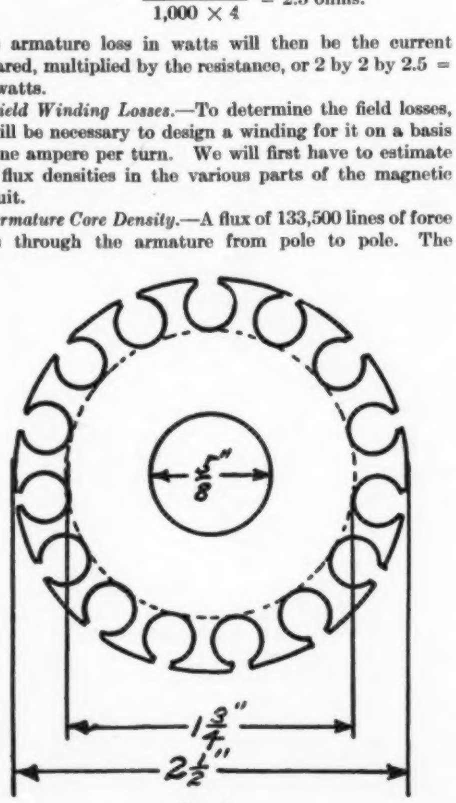


Fig. 3.

diameter of the armature below the teeth is 1¾ inches and its area is 1¾ by 2¼ = 3.9 square inches. The armature core density is then $\frac{133,500}{3.9}$ = 34,300 lines of force per square inch.

Tooth Density.—Since the slots are round, the teeth will not have a uniform width, but will be narrowest in the middle of their length where the maximum tooth density will also occur. The slot centers are on a circle 2⅛ inch in diameter, which circle also passes through the teeth at points of maximum density. The perimiter of a 2⅛ inch circle is 6.6759 inches. The fifteen 5/16-inch slots cut away 15 by 5/16 = 4.6875 inches, leaving 1.9884 inches for the teeth, or 0.1325 inch per tooth. Since five teeth are covered by each pole the flux of 133,500 lines of force passes through an area of 0.1325 by 2.25 by 5 = 1.479 square inches. The maximum tooth density is then $\frac{133,500}{1.479}$ = 90,200 lines of force per square inch. This is satisfactory, for this value may run as high as 100,000 or even 125,000, as the average density is much less. For armatures with straight teeth the limit should be between 90,000 and 100,000 lines of force per square inch.

Pole Core Density.—In determining the pole density,

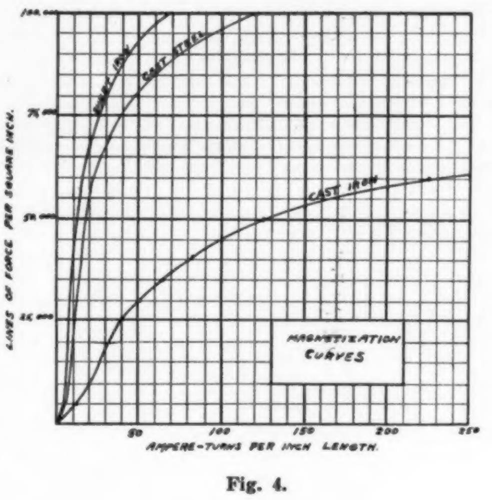


Fig. 4.

we will have to allow for the magnetic leakage, as all the flux leaving the pole does not pass through the armature. A fair value for the leakage factor is 1.25. The corrected flux per pole is then 1.25 by 133,500 = 166,875 lines of force. The pole density is $\frac{166,875}{2 \times 2.25}$ = 37,000 lines of force per square inch. The density in cast-iron may run as high as 45,000 lines of force per square inch; for steel and wrought iron, as high as 65,000 lines of force per square inch.

Yoke Density.—The flux from the pole divides in the yoke, half going each way to the other pole. The yoke area is 5/8 by 4¼ = 2.39 square inches. The yoke density is then $\frac{166,875}{2 \times 2.39}$ = 34,900 lines of force per square inch. This density may be as high as 40,000 lines of force per square inch. For wrought iron and steel, as high as 55,000 lines of force may be used.

Calculation of the Field Winding.—The curves, Fig. 4, plotted in terms of ampere-turns per inch of magnetic circuit length for various densities of lines of force per square inch, give the properties of cast iron, cast steel, and sheet steel. Better curves are obtainable, but the use of higher values in the calculation of these designs will involve the danger of underestimating the required field winding. It will be better for the amateur to confine himself to these curves, which are ample for iron of average qualities.

The next step will be to tabulate all the data of the magnetic circuit as given below and by means of the curves, estimate the necessary magnetizing force.

CALCULATION OF MAGNETIZING FORCE.

Part.	Material.	Circuit Length.	Flux Density.	Ampere Per Inch.	Turns Total.
		Inches.			
Armature Core...	Sheet Steel	1¾	31,300	9	16
Armature Teeth..	Sheet Steel	⅜	90,200	55	41
Pole Core	Cast Iron	2	37,000	75	150
Air Gap..	Air Gay	1.16	25,000	....	490
Total A	mpere Turns.	....	....	....	1,087

The ampere turns for the air gap are obtained from the formula, ampere turns = 0.313 by lines of force per square inch by length of the air gap in inches, and for this, machine are, 0.313 by 25,000 by 1/16 = 488.9 ampere turns. In making this calculation be careful to use the total air gap length which is equal to the difference between the armature and field bore diameters.

On a basis of 800 circular mills per ampere and one ampere per turn, 1,088 turns of No. 21, single cotton-covered magnet wire will be required. No. 21, single cotton-covered wire runs 942 turns per square inch. Allowing 20 per cent for space loss in winding, reduces this figure to approximately 750 turns per square inch.

Dividing the total turns and placing half on each pole, each coil will contain 544 turns requiring a coil having a cross-section of $\frac{544}{750}$ = 0.725 square inch. The poles are long enough to use a coil ¾ inch thick. The cross section of the coils will then be ¾ by one inch. The average turn length will be 2 (2 + 1 + 2,25 + 1) = 12.5 inches. The total length of the field wire will be $\frac{1,088 \times 12.5}{12}$ = 1,126 feet. No. 21 magnet wire has a resistance of 14.28 ohms per thousand feet at 50 deg. Cent. The field winding resistance is then $\frac{14.28 \times 1,126}{1,000}$ = 16 ohms. The current being one ampere, the field loss is then 1 by 1 by 16 = 16 watts.

Available Output.—The armature loss is 10 watts and the field loss 16 watts, making a total loss of 26 watts. The armature generates 89 watts, which, after deducting the losses of 26 watts, leaves 63 watts available at the terminals. The succeeding chapter will take up the design of the machine both as a generator and as a motor.

DESIGN OF A SHUNT WOUND DYNAMO.

In our preliminary design we determined the available output of our machine as 60 watts. Assuming that a winding for 20 volts and 3 amperes is desired, we will work out the final design on this basis. Now for a shunt wound machine the armature will have to generate a voltage equal to the terminal voltage plus the drop in volts, due to the armature resistance.

The armature current for a shunt machine will be equal to the sum of the armature and shunt field currents. The field loss is 16 watts. At 20 volts, the shunt field current will be ¾ ampere. Adding the field current to the available armature current gives 3.75 amperes as the total armature current.

The armature loss is 10 watts. With a current of 3.75 amperes, the voltage drop will be $\frac{3.75}{10}$ = 2.66 volts. The armature should be wound to generate 22.66 volts.

The number of armature conductors to generate 22.66 volts may be obtained by transposing the formula given for armature voltage and substituting values, but a simpler method is by proportion. It was found that 840 conductors generated 44 volts; then $\frac{840 \times 22.6}{44}$ = 432 conductors will be required to generate 22.66 volts. Since there are 15 slots, we will have to place 30 conductors in a slot, making a total of 450 conductors on the armature.

The armature current of 3.75 amperes flows through two paths in the armature. The current per path and also per conductor will than be 1.875 amperes. Allowing 400 circular mills per ampere, a conductor having an area of 750 circular mills will be required. No 21 B. & S. magnet wire, the nearest size, has an area of 810 circular mills and will be satisfactory. Double cotton covered magnet wire should be used for armature windings in

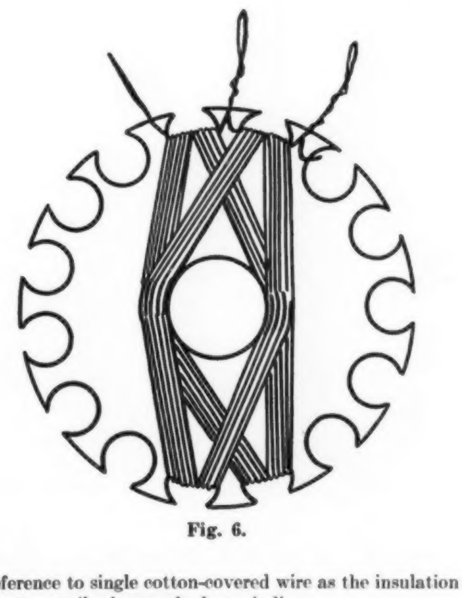


Fig. 6.

preference to single cotton-covered wire as the insulation is not so easily damaged when winding.

It would be well at this point to check the armature voltage drop. Since there are 450 conductors, there will be 225 turns. Taking the average turn length as 10 inches, the length of wire on the armature will be $\frac{225 \times 10}{12}$ = 187.5 feet. No. 21 B. & S. wire has a resistance of 14.28 ohms per thousand feet at 50 deg. Cent. The armature resistance will then be $\frac{187.5 \times 14.28}{1,000 \times 4}$ = 0.669 ohm. Since the total armature current is 3.75 amperes, the drop is 3.75 by 0.669 = 2.5 volts. This is satisfactory as we allowed 2.66 volts.

The armature insulation on low voltage machines may consist of shellacked wrapping paper. For machines of

110 or 220 volts, thin rope paper, fish paper, or other insulating paper should be employed. Wrap several layers of insulation on the shaft on each end of the core, and several discs of insulation should be stuck to the ends of the core with shellac or insulating compound. When this is dry cut the insulation away from the ends of the slots and insert a trough of insulation in each slot, making them long enough to project on each end of the core for a distance of 1/8 inch, so that there will be no possible chance of the wire coming in contact with the core.

Bipolar armatures having an even number of slots are usually wound with the coils in diametrically opposite slots. With armatures having an odd number of slots, the coils will, of course, lie in slots having a slightly shorter span than the armature diameter. Where the number of slots and commutator bars are equal, there will be two coils per slot. The slots are first wound half full, progressing around the armature from slot to slot, and then the second coils are wound upon the first coils.

The scheme of winding and connecting the fifteen slot armature of the design given in this article is shown in Fig. 5. Numbering the slots from 1 to 15 in consecutive order around the core, wind coil 1 in slots 1 and 8; leave out a loop between slots 1 and 2, as shown in Fig. 6, and wind coil 2 in slots 2 and 9; coil 3 in slots 3 and 10; coil 4 in slots 4 and 11; coil 5 in slots 5 and 12; coil 6 in slots 6 and 13; coil 7 in slots 7 and 14; coil 8 in slots 8 and 15; coil 9 in slot 9 and on top of coil 1 in slot 1, leaving a loop between succeeding coils. The next coils will occupy the top of the slots already wound. Coil 10 will then be wound in the top of slots 10 and 2; coil 11 in the top of slots 11 and 3; coil 12 in the top of slots 12 and 4; coil 13 in the top of slots 13 and 5; coil 14 in the top of slots 14 and 6; coil 15 in the top of slots 15 and 7, when the slots will be full. The connections to the commutator are made by connecting the loops to the adjacent commutator segments. Each coil consists of 15 conductors, filling half of the slot, which contains 30 conductors.

If we trace the flow of current through the armature from brushes B1 to B2, Fig. 5, we will find two paths, as indicated by the following, connected in parallel between the brushes. Starting at B1, the first path embraces coils 1-1, 2-2, 3-3, 4-4, 5-5, 6-6, 7-7, 8-8, to B2. The second path embraces coils B1-1, 15-15, 14-14, 13-13, 12-12, 11-11, 10-10, 9-9, to B2.

This scheme of winding and connecting may be carried out with armatures of varying numbers of slots. It would be well to make a diagram similar to the one given before winding the armature.

The shunt field loss is 16 watts. At 20 volts, the current will be 0.75 ampere. The problem then is to design a winding such that it will pass 0.75 ampere at 20 volts. Dividing the voltage by the current gives the resistance of the field as 26.66 ohms.

For a trial we will allow 800 circular mills per ampere. For 3/4 ampere, a conductor having an area of 600 circular mills will be required, corresponding to No. 22, which has an area of 642 circular mills.

To magnetize the magnetic circuit, 1,088 ampere turns are required. At 3/4 ampere, 1,450 turns will be necessary, 725 being wound on each pole. In the preliminary design, the average length of turn was 12.5 inches making the total length of field wire $\frac{1,450 \times 12.5}{12} = 1,510$. The resistance of No. 22 B. & S. wire is 18 ohms per 1,000 feet. The field resistance is $\frac{1,510 \times 18}{1,000} = 27.1$ ohms. This is fairly close and will be satisfactory.

The brushes for low voltage machines should be composed of enough strips of phosphor bronze or copper to give the required contact area, which is about 100 amperes per square inch of contact.

For machines above 50 volts carbon brushes should be used, and the contact density should be about 25 amperes per square inch. The density in small machines may be even less than this because the contact area at a density of 25 amperes would be so small.

DESIGN OF A SHUNT MOTOR.

A generator supplies its own losses in the armature and field, but in a motor these losses are supplied by the line current. Therefore the motor should be designed for its armature output plus losses. In the case of the machine previously designed as a generator the total output designed as a motor would be 89 plus 26 or 115 watts. The armature would be designed for 89 plus 10 or 99 watts, while the field would be the same as for the shunt generator.

Designing the armature for 99, or practically 100 watts at 20 volts, will give an armature current of 5 amperes, or 2 1/2 amperes per path. The area of conductor required is then 2 1/2 by 400 = 1,000 circular mills. This corresponds to No. 20, having an area of 1,020 circular mills.

The number of armature turns is determined as in the design of the shunt dynamo. For 20 volts $\frac{840 \times 20}{44} =$ 382 turns will be required. To distribute this winding in 15 slots, wind 13 turns per coil, or a total of 26 turns per slot. The same armature winding scheme will be used in the motor armature as in the generator armature.

In making these designs, enameled wire may be used, allowing more wire in a given space, which increases the output, but greater care should be exercised in winding to avoid damaging the insulation.

Before starting a machine as a generator, after it has been rewound, magnetize the magnetic circuit with a battery current. It will then retain enough residual magnetism to enable it to start generating. The brush should be placed on a neutral point between the pole tips, and the machine brought up to speed. Running as a generator, the brushes should be given a little lead in the direction of rotation; as a motor, a little lead back of the direction of rotation.

Turbines vs. Engines in Units of Small Capacities*

With Special Reference to the Prime Movers

By J. S. Barstow

The term "units of small capacities" as used herein is intended to include steam turbines and engines of less than 500 h.p. capacity. The paper will necessarily deal largely with the prime movers of auxiliary apparatus in power plants, since the tendency of the times in all industries, and particularly in central stations, is toward the concentration of power in a few units of a large size and uniform capacity as opposed to a multiplicity of small units of different capacities. However, there is a wide field for power application where the steam-operated prime movers are of relatively small size, and where transmitted or central station energy is not able to successfully compete; and it is intended to discuss the type of apparatus best suited in these cases, as well as the type of apparatus which it is advisable to employ for auxiliary units in large plants or central stations.

There are certain definite fields where the small turbine is of conceded superiority, and other fields wherein the engine must hold sway. The desirability of the one as compared with the other is largely determined by the following factors, which govern the adaptability, cost and economy of the equipment to be installed for any given service:

a *Speed conditions and limitations* involving consideration of maximum or minimum permissible speed, and whether the driven apparatus is of the constant or variable speed class.
b *Steam pressure and temperature conditions* involving consideration of initial and final pressures, and superheat, if any.
c *Power capacity of apparatus.*
d *Relative space requirements of turbine and engine units* involving consideration of available room, character of power house construction and cost of foundation or other supporting structure.
e *Use or application, if any, of the exhaust steam* for feed water heating, steam heating or process purposes.
f *Available cooling water supply,* if the turbine or engine is to run condensing, involving also consideration of the temperature of the water and whether it must be artificially cooled and re-circulated.
g *Operating conditions* including consideration of attendance, oiling, starting and stopping, vibration, noise, etc.
h *Relative cost of complete installations* including necessary foundations, piping and condenser equipment, if any.

*Presented at the Philadelphia local section of The American Society of Mechanical Engineers, April 12, 1915.

As to the practicability of the small turbine, it may be said that not until about 20 years ago was any really practicable apparatus of this kind developed, and even up to ten years ago the turbine was looked upon mainly as an experiment. The last few years have witnessed, however, the practical perfection of this type of prime mover in sizes as large as 50,000 h.p., with units of 30,000 h.p. quite common in large central stations. They have also seen quite as much good work done in the perfection of small turbine units as in the development of very large ones, and the turbine in all sizes is quite as well developed to-day as is the steam engine after more than one hundred years of constant effort and improvement.

The writer has no intention of reflecting on the great work done by steam engineers in the development of the reciprocating steam engine. The work of these men, which was the harder task, accelerated the evolution of the turbine, the science of thermodynamics underlying the final development and perfection of both.

The present day builders of reciprocating engines are able to report further progress, however, and as a result of their recent efforts there have appeared the rejuvenated poppet valve engine adapted to the use of highly superheated steam; the uniflow or parallel-flow engine, also with poppet type valves, in which cylinder condensation is reduced by causing the steam to travel in one direction only; and the small self-contained power plant, or "locomobile," consisting of a steam engine mounted upon a tubular boiler and operating at high superheat. All these engines are adaptations from European practice, where, owing to the high cost of fuel and the relatively larger number of technically-trained operators, they have found high favor.

Mention also should be made of the power plant formerly used in the White motor car, which, owing to its high steam pressure, superheat and speed, gave remarkably low steam consumptions. In a series of tests, reported in the *Transactions* of the Society, vol. 28, pages 598-9, the average steam consumption was 12.7 lb. per delivered h.p.-hr., operating at 850 r.p.m.; steam at 275 lb.; superheat, 349 deg. Fahr.; non-condensing exhaust.

Tests have recently been reported by the manufacturers which give the steam consumption of a 115 h.p. Buckeyemobile, running at 248 r.p.m.; steam at 210 lb.; initial superheat, 171 deg. Fahr.; non-condensing, as 13.3 lb. per i.h. p-hr. This unit produced an i.h.p. hr. on 1.33 lb. of coal having a calorific value of 14,500 B.t.u. per. lb. A 169 h.p. unit running at 200 r.p.m.; steam at 209 lb.; initial superheat, 218 deg. Fahr.; vacuum 25.7 in., showed a water rate of 9.2 lb. per i.h.p.-hr. The coal consumption, using fuel with a calorific value of 14,209 B.t.u. per lb., was 1.08 lb. per i.h.p.-hr.

While there is the possibility that the use of a shell type of boiler for high pressures will be considered by many engineers as unwise, especially for installation in densely populated centers, it is still too early to predict what the future of this apparatus is to be. However, as indicating what may be accomplished in fuel economy in a well-designed plant of small size, the results reported are interesting.

SPEED LIMITATIONS.

The question of speed limitations is of first importance in selecting the type of prime mover. Since high peripheral velocities are necessary in order to efficiently utilize the energy of a steam jet in the turbine type of apparatus, the latter shows its lowest water rate when running at a constant high speed. Where the character of the service is such as to require speed variation or reversal in direction, or where the speed is necessarily low, the turbine is unsuited and the engine is much better adapted.

In engine installations, the minimum permissible speed has an important bearing on the question of operation. If an engine is run at very high speeds, operating troubles are sure to be numerous, the upkeep excessive and the service unsatisfactory. The lack of driven apparatus designed to run efficiently at speeds consistent with high turbine economy has, in the past, frequently dictated the use of engine prime movers for many kinds of work.

Although speed reduction gears are by no means new, having been used with the turbine almost from the beginning of its commercial development, improvements in high speed gearing, as well as in the manufacture of high speed direct connected generators, blowers and pumps, running at 3,000 r.p.m. and above, have greatly increased the possibilities for turbine installations. Direct current generators as small as 10 kw. capacity, and 60 cycle alternators of capacities as low as 150 kw., designed for gear drive, are now offered. The manufacturers claim for these machines that the increased efficiency of the higher speed turbine, together with the saving effected in the generator construction by reason of the slower speed permissible in the driven end, justify the expense and complication which the gears introduce.

While many may still prefer a direct connection, the increasing popularity of the gear drive, especially for

direct current generators, blowers and pumps, would seem to indicate that the gears are here to stay, and that when properly constructed and installed, there is no valid objection to their use.

For power station work, where some of the auxiliaries are usually motor driven, the exhaust steam can be entirely condensed in the feedwater heater, and the water rate of the steam driven auxiliaries is not a limiting factor, while reliability, accessibility, low maintenance and labor costs are of more vital importance. Power station designers have always exhibited, therefore, a strong preference for turbo-auxiliary units, and there is now a decided tendency toward geared installations.

The selection of turbines for auxiliaries is largely influenced by the high speed at which small engine units are run; which makes it exceedingly difficult to keep them in continuous service, and almost impossible to secure smooth, quiet operation. Such reciprocating units require close attention, and must be shut down, overhauled and adjusted at frequent intervals; the maintenance is high and serious breakdowns are by no means rare. An accident to a circulating or hot well pump, for example, usually necessitates a shutdown of the main generator, with consequent loss of production, and often, in the case of a public utilities plant, loss of prestige and the incurrence of public ill-will. In all central stations, therefore, where the main units are few in number and of large size, high economy as compared with continuous operation becomes relatively unimportant, and turbine driven circulating hot well and boiler feed pumps are almost invariably used.

Motor driven exciters are largely used in alternating current stations, a steam driven exciter being provided for starting up and as a reserve unit. Here also, since the steam driven set is idle a large part of the time, high economy is not so important and the saving of floor space and elimination of vibration will often decide the question in favor of the turbine. In fact, in all direct current generator sets of 50 kw. capacity or less, the high speed necessary for the engine generally makes it undesirable.

For driving fans of large capacity at low pressures, say less than 1½ in. of water, for induced draft, hot air heating and ventilating systems and the like, the engine seems best suited. Fans built for this service ordinarily run at less than 200 r.p.m. and are usually of the paddle-wheel type, which is better suited to these conditions than the multiblade high speed fan. In induced draft work, load fluctuation may require frequent changes in speed, the engine being under the control of a throttling regulator which is automatically actuated by a change of steam pressure. These conditions are quite unfavorable to turbine economy, and a suitably designed and well-constructed engine will give more satisfactory results.

In like manner, where we consider the pumping of large quantities of water against low variable heads (conditions which are encountered in drainage or sewage pumping stations) the turbine must yield place to its rival. These pumps may have single runners of large diameters or may be of the multi-impeller type, but in either case, the speed is below the economical turbine range, even when a gear is used, while the engine, at low speed, has an opportunity to make its best showing, steam economy and operating troubles considered. Where the lift is variable, speed changes are required and the engine is almost always more suitable.

As a typical installation may be mentioned the four 76-in. centrifugal pumps for the Plaquemine and Jefferson Drainage District of Louisiana. Here the pump speed varies from 50 r.p.m. for 1 ft. head and 135,000 gal. per min. to 115 r.p.m. for 13 ft. head and 90,000 gal. per min. The best duty was 92,600,000 ft. lb. per 1000 lb. of dry steam, corresponding to 21.4 lb. of steam per water horse-power obtained at 87 r.p.m. for 7 ft. head and 130,000 gal. per min. The prime mover is a compound engine operating at 170 lb. steam and 25.7 in. vacuum.

The use of underfeed stokers operating under heavy forced draft and capable of developing high boiler ratings, has become quite common as a means of reducing fixed charges and boiler banking losses in railway and lighting plants, and particularly those maintained as standbys to hydro-electric stations. These furnaces often carry in the air duct pressures as high as 6 in. of water, and the high speed multiblade fan makes the better installation, particularly where one fan serves several boilers, as the blower units frequently become excessively large when run slower than 400 r.p.m. At this speed the engine drive is an uncertain and expensive proposition.

Furthermore, as such stokers at best are capable of only from one quarter to one third their maximum capacity under natural draft conditions, a blower breakdown under a peak load is a serious matter and the ability of the turbine to stand up under the conditions imposed justly entitles it to the preference which it is accorded.

For driving directly connected alternators, a frequency of 25 cycles fixes the maximum speed at 1500 r.p.m., which is too low for the best turbine performance. In 60-cycle apparatus, where a speed of 3600 r.p.m. is possible, the turbine shows to better advantage.

STEAM PRESSURE AND TEMPERATURE CONDITIONS.

The highly economical steam turbine must necessarily be operated condensing, but, as previously pointed out, there are many cases where high steam economy is not the most important consideration and the non-condensing turbine often finds favor over the steam engine. One of the large heat losses incurred in the steam engine is that due to cylinder condensation and one of the common methods of reducing it to limit the range of temperature through which the steam is allowed to work in a single cylinder. For this reason simple engines are better adapted for low steam pressures, while compound and triple expansion engines are advisable for high pressure and high temperature ranges, particularly if the load is uniform.

The engine as a rule develops mechanical troubles with high superheat, especially where the steam valves have much travel under unbalanced pressures. The consensus of opinion seems to be that for slide or gridiron valve gears, a temperature of 400 deg. Fahr. to 425 deg. Fahr. should not be exceeded, while the best point for the Corliss type engine will be found below 450 deg. Fahr. Above these limits lubrication is unsatisfactory and distortion of the parts is apt to give trouble.

In European practice, superheating is much more common than in this country, a superheater being considered quite as indispensable as a feedwater heater, and the poppet valve engine, which was first perfected abroad, is accordingly better suited for high superheat conditions than the type of gear commonly used in American engines.

A difficulty sometimes encountered with engines using high superheat is the warping of the cylinder, the curvature being caused by the higher temperature which prevails in the metal next to the steam chest. Precaution is taken by some builders to avoid such trouble by leading the steam by two independent pipes, entirely separate from the cylinder barrel, from the throttle directly to the steam valves.

For power plant auxiliaries, it would appear that turbines which experience little difficulty from high temperatures will be more and more widely adopted while engines will be less commonly used, especially so as steam pressures and superheats are constantly increasing, it being not unusual for new plants to be designed to carry from 200 to 225 lb. with superheats of 150 deg. Fahr. and over. With steam engines running under high vacua, above 27 in., the great volume of steam to be handled increases the size of the engine cylinders, and the size of ports through which the steam must pass, to such an extent as to make the engines very expensive if not of impracticable construction. The cost of an engine which would permit of complete expansion to such a terminal pressure, together with the increase in cylinder condensation, due to the greater range of temperature, would make the high vacuum undesirable.

The turbine, of the other hand, can be designed to operate on very low terminal pressures with comparatively slight increase of cost; its action as a heat machine is such that a greater expansion can be utilized and the economy is greatly improved by any increase in vacuum. When run non-condensing, as is well known, the turbine is less economical than the non-condensing engine.

In plants where the exhaust is atmospheric and cannot be applied to any useful purpose, the engine best fills the conditions, provided space is available and the speed may be made low enough to insure smooth, quiet running. Such an application is found in direct current generator sets of 100 kw. capacity and larger, in hotels, office buildings and hospitals, where the exhaust is used for steam heating in winter and must be wasted for several months in the year.

POWER CAPACITY OF APPARATUS.

The lower cost of large turbine units and the greater reliability of this kind of apparatus in regular service, coupled with the smaller space taken up by turbines as compared with engines, have practically put the engine out of the running as far as large power plants are concerned. Where 60-cycle apparatus is installed and condensing units are used, the engine has no field beyond the 500 kw. mark, while with direct connected 25-cycle apparatus, the engine must stop beyond the 1000 kw. limit, and with the perfection of high speed reduction gears, it is doubtful if 25-cycle engine driven generators can compete with turbine apparatus of even 500 kw. capacity. The reduction gear is also rapidly driving the engine from the direct current field in units of all sizes, above say 200 kw. capacity. At the same time, elimination of operating troubles by the use of direct connected turbines for exciter purposes is fast causing the turbine to supplant the engine for this service.

In the case of non-condensing units where moderate speeds are required, the engine must continue to hold the field, though special conditions may make the non-condensing turbine a factor to be considered. In this connection, one installation might be mentioned where a belted turbine of 750 h.p. capacity, running at 1500 r.p.m., is used for driving the constant speed shafting of a paper mill, it being contended that the greater uniformity in rotative speed secured by the turbine results in fewer breaks and a more satisfactory product. In this case, the exhaust steam is, of course, utilized in the dryers of the machine, and the variable speed power is supplied by direct current motors.

RELATIVE SPACE REQUIREMENTS.

Owing to the freedom from reciprocating motion, the foundations required for turbines are of small size and light weight, there being little vibration to be absorbed when the alignment and balancing are well done. The small sizes can be safely operated on floors of usual construction, designed for the ordinary floor loads. There is no difficulty experienced with the transmission of vibration to the structural members of the building or to the piping system.

The small space required for the installation of a turbine gives it an advantage in water works plants, operating against moderately high heads. The vertical triple expansion engine, which was formerly used almost exclusively for such work, requires a strong massive substructure to absorb the shock and distribute the weight, and a deep pit to accommodate the water end. Where foundation or other construction difficulties are encountered in this work, the cost may easily climb to a high figure, and in a case under the author's personal observation the additional cost of building, incidental to the use of the vertical triple engine, would have more than paid for a turbine driven centrifugal pump, while the fixed charges on the pump alone were more than four times the cost of the fuel required to run it to full capacity ten hours per day.

The turbine driven pump is not capable of showing on test the high duty of the vertical triple engine—which is one of the most economical steam engines—but the great difference in the first cost of installation often makes the turbo set decidedly preferable, especially when the saving in building is considered. A geared turbine unit to pump 100 million gallons per day against a 56 ft. head was recently installed in Ross Station, Pittsburgh; the pump speed was 350 r.p.m. and that of the turbine 3600 r.p.m. On the duty trial, with steam at 151 lb. and vacuum 28.38 in., the pump showed a performance, including power consumed by the auxiliaries, of 120.5 million ft. lb. per 1000 lb. of dry steam, corresponding to 16.44 lb. of steam per w.h.p-hr. Six similar sets, ranging in capacity from 6½ to 30 million gallons per day capacity, are now in process of construction. The displacement of the reciprocating engine from a field where its superiority was formerly unquestioned, shows the substantial progress which has been made in the development of the steam turbine and the centrifugal pump.

For boiler feed pumps of more than 250 gal. per min. capacity, the turbine is often used, and on account of its small size, usually results in a neater and more compact layout. Where regulation by throttling is necessary, and the pumps run at or near capacity, the economy as compared with the direct acting type is good and can be better maintained. Valve renewal and packing troubles are avoided. The overload capacity of the centrifugal type, however, is small and the delivery of the pump must be proportioned to meet the maximum demand, not the average boiler horse power requirements. In the smaller sizes, the cost of turbine units is high; where the load fluctuates widely and the speed must vary, the economy is poor and it is better to install reciprocating pumps.

In the modern plant containing large turbo-generator units, space limitations in the basement arrangements are an important consideration. With the high vacua carried, large volumes of water must be handled and the turbine drive for circulating, condensation and air removal pumps is in many cases the proper selection. Such condenser sets have a compact arrangement, especially when a single turbine is used to drive all the pumps, which greatly relieves the crowded condition that would otherwise obtain. As previously stated, they are also preferable as being more reliable.

The turbo-compressor supplying air to blast furnaces under pressures ranging from 20 lb. to 30 lb. has almost entirely supplanted the compound reciprocating blowing engine. One large company formerly in this work has abandoned the construction of blowing engines and is now building turbine apparatus exclusively. For this service, the turbine may be run from 2500 to 4000 r.p.m., and there is a great saving of weight and space, as an engine of this type is six or eight times as heavy as the centrifugal blower, and consequently costs much more. It can be installed comfortably where the blowing engine would be out of the question, and in new installations the relative cost of building and foundation for the two types has a direct and important bearing.

UTILIZATION OF EXHAUST STEAM.

The advantage of an oil-free exhaust is in many plants of considerable value, and especially so in manufacturing processes where steam is used, as there are many such opportunities for the utilization of low pressure steam if

the oil has been eliminated. For the blocking of hats and in the treatment of other felt and textile products, absolutely clean steam is necessary. As heretofore mentioned, paper manufacturers have used turbines for driving the constant speed mechanism of paper machines in order to secure more uniform angular velocity, and to avoid among other things trouble caused by oil accumulation in the drying rolls. The danger of oil deposits in high pressure steam boilers is well known to all.

In chemical processes where steam is used for precipitation, as in the precipitation of magnesia, a small fraction of a grain of oil per gallon will often retard the process or cause the precipitate to be of an entirely different character from that obtained with oil-free steam. The separation of the oil in exhaust steam is never absolutely complete, and fatty constituents are especially apt to pass the separator.

AVAILABLE COOLING WATER SUPPLY.

Where the available cooling water supply is limited and must be artificially cooled and recirculated, the cost of the cooling apparatus and the power required must be considered. The conditions will, perhaps, be best illustrated by an example: Assuming a turbine to run at 28 in. vacuum, and a temperature rise of the cooling water to within 10 deg. of that due to the vacuum, the circulation of 52 units by weight of cooling water for each unit of steam condensed will be necessary. In the case of the engine, which will operate at, say, 26 in. vacuum, other conditions remaining the same, there will be from 25 to 27 lb. of cooling water to be handled for each pound of steam condensed.

With a cooling pond returning water at 90 deg. to produce 27 in. vacuum in a turbine plant, the pumps must circulate 70 units of cooling water per lb. of steam, as against, say, 30 units required to produce 25 in. vacuum for the reciprocating engine.

OPERATING ADVANTAGES.

From the operating point of view, the turbine possesses a great advantage in the simplicity of its construction, a factor which tends toward increased reliability and lower cost of maintenance. It can usually be more quickly started and loaded and, in operation, usually requires very much less attention than an engine unit of corresponding capacity. The lubricating arrangements are few in number and of simple design.

SUMMARY.

Summarizing the foregoing, the fields of usefulness of the turbine and engine may be briefly stated to be:

APPLICABILITY OF TURBINES.

1 *Direct connected units, operating condensing.* 60-cycle generators in all sizes, also 25-cycle generators above 1000 kw. capacity. (This paper is, however, not intended to deal with units of this size.)

Direct current generators in sizes up to 1000 kw. capacity, including exciter units of all sizes.

Centrifugal pumping machinery operating under substantially constant head and quantity conditions, and at moderately high head, say from 100 ft. up, depending upon the size of the unit.

Fans and blowers for delivering air at pressures from 1½ in. water column to 30 lb. per sq. in.

2 *Direct connected units, operating non-condensing* for all the above purposes, in those cases wherein steam economy is not the prime factor or where the exhaust steam can be completely utilized, and, in the latter case, particularly where all free exhaust steam is desirable or essential.

3 *Geared units,* operating either condensing or non-condensing for all the above mentioned applications, and in addition, many others which would otherwise fall in the category of the steam engine, on account of the relatively slow speed of the apparatus to be driven.

APPLICABILITY OF ENGINES.

1 *Non-condensing units, direct connected or belted* and used for driving:

Electric generators of all classes excepting exciter sets of small capacity, unless belted from the main engine.

Centrifugal pumping machinery, operating under variable head and quality conditions and at relatively low heads, say up to 100 ft., depending on the capacity of the unit.

Pumps and compressors for delivering water or gases in relatively small quantities and at relatively high pressures—in the case of pumps at pressures above 100 lb. per sq. in. and in the case of compressors at pressures from 1 lb. per sq. in. and above.

Fans and blowers (including induced draft fans) for handling air in variable quantities and at relatively low pressures, say not over 5 in. water column.

Line shafts of mills, where the driven apparatus is closely grouped and the load factor is good.

All apparatus requiring reversal in direction of rotation, as in hoisting engines and engines for traction purposes.

2 *Condensing units direct connected or belted,* for all the above purposes, particularly where the condensing water supply is limited, and where the water must be re-cooled and re-circulated.

Chemical and Physical Properties of Lime

LIME, chemically, is the oxide of calcium (CaO), but the commercial article may differ very widely from this composition. It may contain anywhere from 0 per cent to 44 per cent of magnesium oxide, and it generally contains more or less impurities, such as silica and oxides of iron and aluminium. When properly burned and fresh from the kiln, it should contain no water and less than 0.5 per cent of carbon dioxide. If the impurities added by the combination between the lime and the brick lining of the kiln be neglected, the composition of any lime will be essentially the same as that of the stone from which it was burned, minus the carbon dioxide.

When lime is slaked the calcium oxide combines with water to form calcium hydroxide. The impurities may be present in chemical combination with the calcium oxide, in which event they also may take up some water. The manufacturers of hydrated lime judge from the gain in weight of their product that magnesium oxide when burned at the temperature of an ordinary limekiln hydrates very slowly, if at all. Nine samples of magnesian hydrates analyzed by the Bureau of Standards showed an average content of 30.92 per cent magnesium oxide and 2.29 per cent magnesium hydroxide. This peculiarity has been made the subject of scientific research, the conclusions from which are that magnesium oxide will combine with water with reasonable rapidity only when it has been burned at some temperature below 1,100 deg. Cent. (This is somewhat lower than the temperature of an ordinary limekiln).

The hydration of calcium oxide generates heat. Since a large part of the magnesium oxide does not hydrate, it acts merely as an inert substance which must be heated by the calcium oxide. Therefore, other things being equal, the less magnesium oxide present in a lime, the more quickly will it slake and the greater will be the heat generated.

The porosity of the lime plays a very important part here, however. Thus, the more porous the lime, the more quickly can the water penetrate it, and hence the chemical combination will take place more readily. Indeed, in some cases the porosity seems to be of more importance than the chemical composition, that is, a very porous magnesian lime may slake more quickly than a dense lime with a much higher content of calcium oxide.

If lime is underburned the calcium carbonate left in it acts as inert matter. Overburned lime exhibits the same phenomenon, although in this case it is probably due to a diminution of the quantity of active calcium oxide present. At the higher temperatures this material combines with the impurities, and hence is not free to take part in the reaction of slaking.

The appearance of unburned lime varies with that of the stone, and can be distinguished only by one who has had practice with the particular lime in question. Overburned lime is generally yellow or black in color and can be readily separated from good lime.

When lime is exposed to the air it absorbs water and carbon dioxide, and "air slakes." This reaction takes place in two more or less distinct stages, first, the absorption of water, and second, the displacement of the water by carbon dioxide. Since these reactions are slow, it is possible to obtain lime which has air slaked to almost any degree, and this has led to a great confusion in the literature in regard to the properties of air-slaked lime. For instance, at one stage of the process (when the water has been absorbed and has not been displaced to any extent), the product is similar in composition to "water-slaked" or hydrated lime. In order to avoid such confusion, the Bureau of Standards has designated as "air-slaked" lime only that product in which the process has been completed, that is, air-slaked lime must be composed chiefly of calcium carbonate or of a mixture of calcium and magnesium carbonates, and therefore it is chemically similar to natural limestone. Any intermediate product will be designated as partially air-slaked.

The absorption of water during the process of air slaking involves a large increase in volume, and therefore the lumps fall to pieces. This fact gave rise to the demand for "lump lime," the consumer being of the opinion that all fine lime is air slaked. There are several grades of limestone which fall to pieces in the kiln. The stone may be so soft that it is broken up by the abrasion; it may have its pores filled with water, which when heated shatters the stone; or its component crystals may be bound together by organic matter which is consumed in the kiln. Stones like these are burned, and in some cases over 50 per cent of the output of the kiln is fine stuff. Such fine lime is as good for all purposes as lump lime, and it is easier to handle and will keep better. This is obvious from the consideration that the top layer of fine lime will air slake and the crust of inert material so formed will prevent access of the air to the quicklime underneath. The old prejudice against fine lime is rapidly losing ground, as is shown by the fact that some manufacturers are putting crushed lime on the market.

The weight of a lump of lime is about 55 per cent of the weight of the stone from which it was burned. Owing to the fact that the lime is in lumps the weight of it which any given volume will contain varies very widely. Thus, a barrel of lime contains from 150 to 350 pounds net in different localities, and a bushel from 32 to 88 pounds.—*Mineral Resources of the U. S., 1913, Part II, U. S. Geological Survey.*

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